BULLETIN

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THE MAINTENANCE OF SOIL FERTILITY

A QUARTER CENTURY'S WORK WITH MANURE AND FERTILIZERS

PLANS AND SUMMARY TABLES

OF THE FIELD EXPERIMENTS AT THE CENTRAL FARMS, WOOSTER, AND THE DISTRICT EXPERIMENT FARMS AT STRONGSVILLE, GERMANTOWN, CARPENTER AND FINDLAY

ANNOUNCEMENT

The experiments reported in the following pages were begun in 1893, immediately after the removal of the Experiment Station to Wooster, Wayne County. The general plan of the work at Wooster and Strongsville, and the results attained up to that time were published in Bulletin 110, issued in December, 1899 (now out of print), and again in Bulletins 182, 183 and 184, reporting to the end of 1906. These publications were followed until 1913 with annual statements, giving as briefly as possible the new data from each successive crop, and referring the reader to Bulletins 182 and 183 for more complete information respecting the nature of the soils under experiment and the general plan of the work, and to Bulletin 184 for the statistics of crop yields for the years 1894 to 1906, inclusive.

The results at Wooster for 1907 are given in Circular 83, those for 1908 in Circular 92, those for 1909 in Circular 104, those for 1910 in Circular 114, those for 1911 in Circular 120, those for 1912 in Circular 131, and those for 1913 in Circular 144, in which the results were given for 20 years and for four 5-year periods.

The details for the earlier years of the work at Germantown have been published in Bulletins 161, 172, 182, 184, 206 and 285; for that at Carpenter in Bulletins 182 and 184, and for that at Findlay in Bulletins 241 and 303.

The present bulletin contains only the average data for these experiments for the entire term of the work, and for 5-year and 6-year periods.

In addition to the work described in this bulletin similar experiments are in progress on county experiment farms in Paulding, Miami, Hamilton, Clermont, Washington, Belmont, Mahoning, Trumbull and Madison counties, which are reported in Bulletins 241, 256, 258, 272, 273, 274, 275, 286, 303 and 323.

THE SOILS UNDER EXPERIMENT

The soil of the Wooster farms is a yellowish-brown, mealy silt loam, underlaid by a brownish-yellow, friable silt loam subsoil, lying upon the shaly sandstones of the upper Waverly series. The surface contains a high percentage of silt with a little very fine sand and less than 20 percent of clay, so that it has but little plasticity, although it runs together after a rain. It washes badly where the sod is destroyed, is easily worked and very responsive to treatment. In general character it resembles the lighter phases of the Volusia silt loam into which it merges to the northward.

The Strongsville soil is a brownish-gray, silty clay loam, classed as Trumbull clay loam, a member of the Volusia series. It is a much heavier and colder soil than that of the Wooster farms and is less responsive to treatment. It lies over an argillaceous shale of the lower Waverly series. Both the Wooster and Strongsville soils have been somewhat modified by glaciation, but the underlying rocks have been the chief factor in their formation.

The Germantown soil is a silty clay loam of the Miami series, lying over glacial gravels largely derived from limestones.

The Carpenter soil is a typical Dekalb silt loam, formed from the decomposition of the sandstones and shales of the barren coal measures.

The soil at Findlay is a Miami silt loam or clay loam derived chiefly from limestones and limestone gravels modified by glaciation.

All the land in these experiments had been in cultivation for many years before the experiments were begun, except a part of that in the potato rotation at Wooster, which was cleared from the forest for the purposes of this experiment; that at Strongsville, which had been in pasture for 25 years or longer, and that at Findlay, which had been used as a fairground.

All the land has been drained with tile drains laid 30 inches deep and 36 feet apart, except the new land in the potato rotation.

PERSONNEL

In the planning and general supervision of these experiments the late J. Fremont Hickman was associated with the Director of the Station until his death in 1902. Since then C. G. Williams has carried the work forward. Throughout the entire 25-year period William Holmes, Farm Manager, has been responsible for the field operations connected with the work at Wooster, assisted by C. H. Lebold and C. A. Patton as Assistant Foremen. W. J. Green has conducted the experiments with potatoes throughout the 25 years of the test, assisted during recent years by Ora Flack, Foreman. The field work at Strongsville was conducted for about 20 years by Edward Mohn, and since then by J. P. Markley. That at Germantown has been in charge of Henry M. Wachter since its beginning, and that at Carpenter was conducted by Lewis Schultz until 1917. J. A. Sutton has been in charge of the work at Findlay from the beginning. Whatever success this work has attained has been due to the faithful cooperation of these men.

THE WOOSTER EXPERIMENTS

I: FERTILIZERS AND MANURE ON CROPS GROWN CONTINUOUSLY ON THE SAME LAND

Wheat, oats and corn, 1 acre (10 plots) each, have been grown in this experiment since 1894. The fertilizers are applied to Plots 2 and 8 in arbitrary quantities, while on Plots 3 and 9 the three fertilizing elements, nitrogen, phosphorus and potassium, are given in approximately the same ratio to each other in which they are found in the plant.

The applications to Plots 2 and 8 have in every case produced larger average yields than those to Plots 3 and 9, but this may be accounted for in part by the combined nitrogen which is carried to the soil in rain, thus enabling the crops grown on 2 and 8 to utilize larger quantities of the phosphorus and potassium given in the fertilizer than that required merely to balance the fertilizer nitrogen.

The manure applications on Plots 5 and 6 were intended to carry nitrogen in quantities equivalent to the applications on Plots 2 and 3 on the one hand and 8 and 9 on the other, estimating the manure to carry 10 pounds of nitrogen per ton, but actual analyses of manure made during recent years indicate that this estimate was too high for open yard manure, such as is used in these tests.

In this test the corn and wheat show a rapid falling off in yield on the unfertilized land during recent years. The oats also show a reduction in yield, but not so great as that of the other crops.

It is much more difficult to control the weed growth in the wheat and oats grown continuously than where same crops are grown in rotation, and it was necessary a few years ago to divide these tracts and fallow the two ends in alternate seasons in order to destroy the weeds. Latterly the entire plots have been cropped again.

Diagram I shows the arrangement of plots and plan of fertilizing in this experiment, and the general outcome is shown in Tables I and II, which give the yields by periods.

For wheat part of the nitrogen ration is given in the fall in dried blood, and the remainder in April in nitrate of soda, sown broadcast.

CALCULATION OF INCREASE

In calculating the increase in the following tables, it is assumed that variations in the soil are progressive and that if the yields on Plots 1 and 4 were 6 and 9 bushels, respectively, Plots 2 and 3 should have yielded 7 and 8 bushels, respectively, if left unfertilized. While, of course, this regular variation will not always occur, experience has shown that in general this method of computation most nearly approximates the true result.

DIAGRAM I: PLAN OF FERTILIZING IN CONTINUOUS CULTURE

PLOTS ONE-TENTH ACRE

		Fertilizing materials in pounds per acre
Wheat	1	None
	2	Acid phosphate, 160; muriate of potash, 100; nitrate of soda, 120; dried blood, 50
	3	Acid phosphate, 45; muriate of potash, 30; nitrate of soda, 170; dried blood, 50
	4	None
	5	Yard manure, 2½ tons
	6	Yard manure, 5 tons
	7	None
	8	Acid phosphate, 160; muriate of potash, 100; nitrate of soda, 280; dried blood, 50
	9	Acid phosphate, 90; muriate of potash, 60; nitrate of soda, 280; dried blood, 50
	10	None
Oats	1	None
	2	Acid phosphate, 160; muriate of potash, 100; nitrate of soda, 160
	3	Acid phosphate, 55; muriate of potash, 50; nitrate of soda, 160
	4	None
	5	Yard manure. 2½ tons
	6	Yard manure, 5 tons
	7	None
	8	Acid phosphate, 160; muriate of potash, 100; nitrate of soda, 320
	9	Acid phosphate. 110; muriate of potash, 100; nitrate of soda, 320
	10	None
Corn	1	None
	2	Acid phosphate, 160; muriate of potash, 100; nitrate of soda, 160
	3	Acid phosphate, 60; muriate of potash, 30; nitrate of soda, 160
	4	None
	5	Yard manure, 2½ tons
	6	Yard manure, 5 tons
	7	None
	8	Acid phosphate, 160; muriate of potash, 100; nitrate of soda, 320
	9	Acid phosphate, 120; muriate of potash, 60; nitrate of soda, 320
	10	None

(South)

TABLE I: CROPS GROWN IN CONTINUOUS CULTURE:

Average annual yield and increase per acre for 25 years, 1894-1918

Plot	Treatment Pounds per acre	Grain		Stover or straw	
		Yield Bu.	Increase Bu.	Yield Lb.	Increase Lb.
	Corn				
1	None	20.06	.....	1,377	.....
2	Acid phosphate, 160; muriate potash, 100; nitrate soda, 160	40 09	22.15	2,199	898
3	Acid phosphate, 60; muriate potash, 30; nitrate soda, 160	31.66	15.85	1,820	596
4	None	13.69	.....	1,148	.....
5	Yard manure, 2½ tons	25.40	11.95	1,682	541
6	Yard manure, 5 tons	35.66	22.44	2,056	922
7	None	12.98	.....	1,127	.....
8	Acid phosphate, 160; muriate potash, 100; nitrate soda, 320	44.93	32.91	2,298	1,227
9	Acid phosphate, 120; muriate potash, 60; nitrate soda, 320	42 15	31.08	2,144	1,128
10	None	10 11	.....	961	.....
	Average unfertilized yield	14.21	.....	1 165	.....
	Oats				
1	None	20.17	.....	807	.....
2	Acid phosphate, 160; muriate potash, 100; nitrate soda, 160	41.05	20.43	1,992	1,169
3	Acid phosphate, 55; muriate potash, 50; nitrate soda, 160	37.29	16.22	1,668	828
4	None	21.52	.....	856	.....
5	Yard manure, 2½ tons	29.85	8.13	1,250	359
6	Yard manure, 5 tons	37.39	15.47	1,843	918
7	None	22.12	.....	960	.....
8	Acid phosphate, 160; muriate potash, 100; nitrate soda, 320	47.54	25.01	2,563	1,604
9	Acid phosphate, 110; muriate potash, 100; nitrate soda, 320	45.62	22.68	2,396	1,437
10	None	23.35	.....	957	.....
	Average unfertilized yield	21.82	.....	899	.....
	Wheat				
1	None	7.56	.....	1,057	.....
2	Acid phos., 160; mur. potash, 100; nit. soda, 120; dried blood, 50	19.74	11.97	2,579	1,553
3	Acid phos., 45; mur. potash, 30; nit. soda, 120; dried blood, 50	15.72	7.73	1,944	947
4	None	8.19	.....	966	.....
5	Yard manure, 2½ tons	14.32	6.14	1,784	813
6	Yard manure, 5 tons	18.79	10.61	2,377	1,403
7	None	8.17	.....	979	.....
8	Acid phos., 160; mur. potash, 100; nit. soda, 280; dried blood, 50	22.79	15.05	3,024	2,096
9	Acid phos., 90; mur. potash, 60; nit. soda, 280; dried blood, 50	20.93	13.61	2,554	1,676
10	None	6.90	.....	827	.....
	Average unfertilized yield	7.70	.....	988	.....

TABLE II.—CROPS GROWN IN CONTINUOUS CULTURE AT WOOSTER

Average annual yield and increase per acre by 5-year periods

Plot No.	Grain					Stover or straw					Plot No.
	1894-98 Bu.	1899-03 Bu.	1904-08 Bu.	1909-13 Bu.	1914-18 Bu.	1894-98 Lb.	1899-03 Lb.	1904-08 Lb.	1909-13 Lb.	1914-18 Lb.	
Corn—yield											
1	29.19	21.85	17.09	15.82	16.36	1,449	1,234	1,546	1,490	1,166	1
2	44.61	47.21	38.50	36.41	33.71	2,076	2,202	2,520	2,496	1,700	2
3	38.86	39.09	28.00	26.83	25.53	1,770	1,820	2,138	2,016	1,356	3
4	28.86	16.81	9.09	6.34	7.31	1,436	1,106	1,162	1,220	816	4
5	36.44	29.21	23.77	18.92	18.67	1,670	1,588	1,958	1,830	1,364	5
6	43.13	40.11	34.62	30.22	30.19	1,938	1,924	2,404	2,296	1,716	6
7	25.53	15.74	8.86	6.95	7.77	1,304	1,060	1,232	1,204	834	7
8	44.43	52.55	44.55	45.82	37.29	2,008	2,376	2,568	2,698	1,842	8
9	42.76	50.13	41.73	41.97	34.14	1,870	2,232	2,458	2,512	1,650	9
10	21.44	12.65	6.64	4.63	5.16	1,170	934	996	970	736	10
*	26.26	16.76	10.43	8.44	9.15	1,339	1,083	1,231	1,221	888	
Corn—increase											
2	15.53	27.03	24.08	23.75	20.36	630	1,013	1,394	1,096	651	2
3	9.88	20.59	16.25	17.33	15.20	330	671	848	706	423	3
5	8.68	12.75	14.75	12.38	11.20	278	497	773	615	542	5
6	16.49	24.01	25.65	23.48	22.57	590	851	1,195	1,087	888	6
8	20.26	37.85	36.41	39.64	30.39	749	1,358	1,415	1,572	1,041	8
9	19.96	36.45	34.34	36.56	28.10	655	1,256	1,383	1,464	881	9
Oats—yield											
1	26.87	16.75	20.40	15.54	21.29	892	578	855	815	893	1
2	42.22	40.11	45.46	34.47	43.01	1,697	1,701	2,136	2,204	2,224	2
3	38.75	36.47	40.79	30.89	39.55	1,470	1,463	1,890	1,710	1,805	3
4	28.67	19.66	21.80	18.15	19.34	1,059	697	855	915	755	4
5	30.83	28 51	35.03	26.09	28.79	1,021	1,030	1,565	1,447	1,186	5
6	34.81	36.76	44.10	33.84	37.44	1,265	1,516	2,232	2,212	1,990	6
7	27.94	21.82	22.55	18.81	19.48	1,110	846	974	1,064	805	7
8	48.75	48.87	47.89	40.70	51.48	2 086	2,342	2,675	2,816	2,897	8
9	46.94	47.36	45.61	38.89	49.31	1 982	2,131	2,548	2,669	2,647	9
10	29.28	23.43	22.98	19.45	21.59	1,125	856	936	1,019	850	10
*	28.19	20.41	21.93	18.14	20.43	1,046	744	905	953	826	
Oats—increase											
2	14.75	22.39	24.59	18.06	22.36	749	1,083	1 279	1,356	1,377	2
3	10.67	17.78	19.46	13.60	19.56	467	806	1,037	628	1,004	3
5	2.40	8.13	12.98	7.72	9.41	—55	283	670	482	415	5
6	6.63	15.67	21.83	15.25	18.00	173	720	1,297	1,198	1,202	6
8	20.37	26.51	25.17	21.68	31.30	971	1,493	1,712	1,767	2,076	8
9	18.10	24.46	22.80	19.65	28.42	862	1,478	1,601	1,625	1,812	9
Wheat—yield											
1	10.56	7.86	5.95	5.10	8.34	1,334	926	1,038	896	1,089	1
2	19.78	21.90	17.41	17.28	22.32	2,205	2,420	2,701	2,559	3,012	2
3	16.33	16.90	13.31	14.80	17.25	1,720	1,644	2,158	2.039	2,157	3
4	10.26	8.76	6.68	6.16	9.08	1,044	940	973	845	1,029	4
5	13.28	14.26	12.23	14.09	17.75	1,475	1,498	1,973	1,913	2,060	5
6	15.77	18.46	17.48	18.75	23.48	1,743	2,014	2,670	2,542	2,917	6
7	9.95	9.38	6 11	5.96	9.44	1,045	965	1,025	871	989	7
8	20.69	25.26	20.88	22.04	25.09	2,510	2,724	3,208	3,191	3,488	8
9	19.01	22.45	19.12	20.06	25.99	2.159	2,181	2,846	2,641	2,940	9
10	9.55	7.62	6.00	4.38	6.94	1,051	805	858	648	775	10
*	10.08	8.41	6.19	5.40	8.45	1,110	909	943	765	975	
Wheat—increase											
2	9.32	13.73	11.21	11.82	13.74	967	1,489	1,684	1,680	1,943	2
3	5.97	8.42	6.87	8.99	8.41	579	709	1,163	1,178	1,108	3
5	3.13	5.28	5.74	7.99	8.55	430	550	982	1,060	1,045	5
6	5.72	9.28	11.18	12.72	14.15	698	1,057	1,663	1,680	1,915	6
8	10 87	16.47	14.80	16.60	16.48	1,463	1,810	2,239	2,394	2,570	8
9	9.33	14.25	13.10	15.15	16.22	1,110	1 323	1,933	1,919	2,094	9

*Average unfertilized yields.

TABLE III.—RECOVERY OF FERTILIZING ELEMENTS IN CROPS GROWN CONTINUOUSLY ON THE SAME LAND. FIVE-YEAR AVERAGES

Crop	Plot No.	Given in fertilizers			Recovered in increase			Percentage recovered		
		Nitrogen Lb.	Phosphorus Lb.	Potassium Lb.	Nitrogen Lb.	Phosphorus Lb.	Potassium Lb.	Nitrogen Percent	Phosphorus Percent	Potassium Percent
Fertilized land										
Corn 1909-13	2	25	11.2	41	33.8	3.6	13.2	135	32	32
	3	25	4.2	12	24.0	2.6	9.1	96	62	76
	8	50	11.2	41	53.4	5.3	18 8	106	48	45
	9	50	8.4	24	50.3	5.0	17.5	100	60	73
Oats 1914-18	2	25	11.2	41	22.4	4.2	19.4	89	37	47
	3	25	3.8	20.5	18.4	3.5	14.5	74	90	70
	8	50	11.2	41	32.2	6.0	28.4	64	53	70
	9	50	7.7	41	28.8	5.3	25.0	58	69	61
Wheat 1914-18	2	25	11.2	41	26.5	4.6	19.0	106	41	46
	3	25	3.1	12	15.8	2.7	11.1	63	87	90
	8	50	11.2	41	33.0	5 7	24.8	66	51	60
	9	50	6.3	24	30.2	5.3	20.8	60	84	80
Manured land										
Corn 1909-13	5	22	4.5	14	18.0	2.1	8.3	82	47	59
	6	44	9.2	28	33.5	3.9	15.0	76	43	54
Oats 1914-18	5	22	4.5	14	8.5	1.6	6.3	39	35	45
	6	44	9.2	28	18.6	3.4	16.4	42	38	59
Wheat 1914-18	5	22	4.5	14	15.6	2 7	11 3	71	60	80
	6	44	9.2	28	26.8	4 7	18.9	60	52	69

In Table III are shown (1) the quantities of nitrogen, phosphorus and potassium given per acre in this test, the quantities given in manure being estimated on the basis of numerous analyses of openyard manure as produced at the Station; (2) the quantities of these elements recovered in the increase of crop during the fourth 5-year period for corn and during the fifth period for wheat and oats, as indicated by average analyses of similar crops produced at the Station, and (3) the percentage which this increase is of the amount given in either fertilizers or manures.

The table indicates that in the corn crop larger quantities of nitrogen were recovered in the increase than had been given in the fertilizer. A part of this excess may be accounted for in the nitrogen brought down in rainfall; a part may be due to the capture of nitrogen by such organisms as the azotobacter, and a part to exhaustion of the original store of nitrogen in the soil—an explanation which is supported by the rapid reduction in yield of the unfertilized land, the decrease in the unfertilized yield of corn between the first and last 5-year periods having been 65 percent, as against a fall of 35 percent for oats and 46 percent for wheat.

In the case of the wheat crop the excess of nitrogen shown in the crop increase would be fully accounted for in the 3 or 4 pounds of nitrogen brought to the earth by rain and snow during the months when the land is occupied by this crop, but in addition to this, for the crops of 1909 to 1916, inclusive, soybeans have been sown broadcast early in August on the east half of the wheat acre as soon as the land could be plowed after harvesting the wheat, the beans being disked in just before seeding the next crop of wheat. In 1917 and 1918 sweet clover was substituted for the soybeans, being sown on the wheat in March. The beans and clover have been sown over all the land, fertilized and unfertilized alike.

Thus far there has been no apparent gain for the catch crops.

The phosphorus and potassium given in the fertilizers have never been fully recovered in the increase of crop.

The outcome of this experiment, therefore, is that if cereal crops are grown continuously on the same land there must be nearly as much nitrogen and considerably more phosphorus and potassium supplied in fertilizers or manure than will be found in the increase over the unaided yield of the land.

II: THE 5-YEAR ROTATION

In this experiment corn, oats, wheat, clover and timothy are grown in succession on five tracts or "sections" of land, A, B, C, D and E, containing 30 one-tenth acre plots each. Sections A and B of this test lie in range VIII, south of the areas devoted to continuous cropping, while Sections C, D and E occupy Range IX, near the east side of the farm.

The land was underdrained in 1893 and corn was grown that season on Section C. The planting was delayed by the draining and the season proved unfavorable, so that the results of that season's work have not been included in the average. In 1894 wheat was harvested on Section A, oats on Section C and corn on Section D. The clover and timothy followed the wheat on Section A in 1895 and 1896, and the rotation has since been regularly followed.

Beginning with 1900, lime has been applied to the west half of each plot in this rotation, fertilized and unfertilized alike, while the land was being prepared for corn, the lime being applied at the rate of 1 ton per acre of ground quicklime, applied in the spring of 1900, 1901 and 1902 after plowing, and in the fall of 1903 for the crop of 1904. In 1905 the liming was changed to the east half, 1 ton of quicklime being used that spring, but in 1906 and 1907 ground limestone was used, at the rate of 2 tons per acre. No lime was applied in 1908, but since then it has been applied to the west half as at the beginning, except that ground limestone has been used instead of quicklime. Table IV gives the average yield for the entire plot in each case, averaging the limed and unlimed halves.

In 1895 and 1896, and again in 1890, 1900 and 1901, the wheat in this test was injured by Hessian fly, the yield on the unfertilized land falling to a small fraction more than 1 bushel per acre in 1896 and 1900. The wheat was again injured by Hessian fly in 1911, and also by joint worm. In 1912 these pests again prevailed, and in addition the winter conditions were such as to cause a partial to complete destruction of the wheat crop over the major portion of the State, the level lands of western Ohio suffering the most severely. The corn in this experiment was severely injured by white grubs in 1910 and 1912, the injury in 1912 being so great that no comparisons could be made.

The clover seeding failed to catch in 1904 and soybeans were grown instead and harvested as hay, the timothy crop of the following year being replaced by German millet. The timothy failed in 1909 and 1915, as did the millet sown in its place, so that no crop of either was harvested in those seasons.

Diagram II shows the arrangemeent of plots and plan of fertilizing one of the sections in this experiment, the five sections being arranged and treated exactly alike. Tables IV, VI, VIII and X give the average yields and increases per acre for the entire period for corn, oats, wheat, clover and timothy, respectively. Tables V, VII, IX and XI give the average yields and increases by 5-year periods.

DIAGRAM II: PLAN OF FERTILIZING IN 5-YEAR ROTATION

Plots one-tenth acre—Fertilizing materials in pounds per acre

Plot No.	On corn			On oats			On wheat			
	Acid phosphate	Muriate of potash	Nitrate of soda	Acid phosphate	Muriate of potash	Nitrate of soda	Acid phosphate	Muriate of potash	Dried blood	Nitrate of soda
1	....	....	....	....	....	....	....	....	....	....
2	80	....	....	80	....	....	160	....	.. .	....
3	. ..	80	....	....	80	....	....	100	....	....
4	....	....	....	....	....	....	....	....	....	....
5	....	....	160	....	....	160	....	....	50	120
6	80	....	160	80	....	160	160	....	50	120
7	....	....	....	....	....	....	....	....	....	....
8	80	80	....	80	80	....	160	100	....	....
9	....	80	160	....	80	160	....	100	50	120
10	....	....	....	....	....	...	....	....	....	....
11	80	80	160	80	80	160	160	100	50	120
12	80	80	240	80	80	240	1f0	100	50	200
13	....	....	....	....	....	....	....	....	....	....
14	80	80	160	....	....	....	160	100	50	120
15	....	. ..	....	....	....	....	160	100	50	120
16	....	....	....	....	....	....	....	....	....	....
17	160	80	80	160	80	80	160	100	25	60
18	Barnyard manure, 8 tons each on corn and wheat									
19	....	....	....	....	....	....	....	....	....	....
20	Barnyard manure, 4 tons each on corn and wheat									
21	Same elements as 17, but nitrogen in oilmeal									
22	....	....	....	....	....	....	....	....	....	....
23	Same elements as 17, but nitrogen in dried blood									
24	Same elements as 17, but nitrogen in sulphate ammonia									
25	....	....	....	....	....	....	....	....	....	....
26	Same elements as 11, but phosphorus in bonemeal									
27	Same elements as 17, but nitrogen in nitrate of lime									
28	. ..	....	....	....	....	....	....	....	....	....
29	Same elements as 11, but phosphorus in basic slag									
30	Same elements as 17, but nitrogen in tankage									

Note: During the first 5 years the quantities of elements on Plots 17, 21, 23 and 24 were the same as on Plot 11, and those of nitrogen and potassium on Plot 30 were smaller. Previous to 1910 Plot 27 received the same quantities of elements as Plot 11, nitrogen being given in nitrate of soda and phosphorus in dissolved boneblack.

TABLE IV.—Yield and increase per acre of CORN grown in 5-year rotation at Wooster. 25-year averages, 1894-1918

Plot No.	Fertilizing materials	Grain		Stover	
		Yield	Increase	Yield	Increase
	Pounds per acre	*Bu.*	*Bu.*	*Lb.*	*Lb.*
1	None	28.38	.....	1 584	.....
2	Acid phosphate, 80	35.49	7.43	1,785	210
3	Muriate potash, 80	33.22	5.47	1,851	287
4	None	27.43	.....	1 555	.....
5	Nitrate soda, 160	33.29	5.42	1 769	205
6	Acid phosphate, 80; nitrate soda, 160	42.79	14.47	1 942	369
7	None	28.77	.....	1 582	.....
8	Acid phosphate, 80; muriate potash, 80	43.75	15.42	2 120	554
9	Muriate potash, 80; nitrate soda, 160	35.47	7.58	1 896	345
10	None	27.44	.....	1 536	.....
11	Acid phosphate, 80; muriate potash, 80; nitrate soda, 160	46.82	19.30	2 239	693
12	Acid phosphate, 80; muriate potash, 80; nitrate soda, 240	47.07	19.47	2,236	679
13	None	27.68	.....	1,568	.....
14	Acid phosphate, 80; muriate potash, 80; nitrate soda, 160	43.80	16.82	2,125	562
15	Fertilized on wheat only	33.13	7.79	1 782	251
16	None	25.59	.....	1,551	.....
17	Acid phosphate, 160; muriate potash, 80; nitrate soda, 80	46.43	20.26	2,202	651
18	Barnyard manure, 8 tons each on corn and wheat	52.55	25.41	2,435	867
19	None	28.56	.....	1,631	.....
20	Barnyard manure, 4 tons each on corn and wheat	42.95	15.00	2,112	491
21	Same elements as 17, but nitrogen in oilmeal	46.28	18.94	2,204	595
22	None	26.73	.....	1,598	.....
23	Same elements as 17, but nitrogen in dried blood	46.36	18.76	2,210	584
24	Same elements as 17, but nitrogen in sulphate ammonia	46.71	18.24	2,225	571
25	None	29.34	.....	1,682	.....
26	Same elements as 11, but phosphorus in bonemeal	44.66	14.85	2,237	543
27	Same elements as 17, but nitrogen in nitrate of lime	46.34	16.06	2,230	522
28	None	30.75	.....	1,721	.....
29	Same elements as 11, but phosphorus in basic slag	46.35	15.60	2,306	585
30	Same elements as 17, but nitrogen in tankage	46.61	15.86	2 206	485
	Average unfertilized yield	28.06	.....	1,600	.....
	Average increase from fertilizers	.....	14.91	.....	498

*Fertilized on corn and wheat only.

†During the first 5 years the quantities of elements were the same on Plots 17, 21, 23 and 24 as on Plot 11, and those of nitrogen and potassium on Plot 30 were smaller. Previous to 1910 Plot 27 received the same quantities of elements as Plot 11.

TABLE V.—Yield and increase per acre of CORN grown in 5-year rotation at Wooster. 5-year averages

Plot No.	5 yrs., 1894-1898		5 yrs., 1899-1903		5 yrs., 1904-1908		5 yrs., 1909-1913		5 yrs., 1914-1918		Plot No.
	Yield	Increase	Yield	Increase	Yield	Increase	Yield	Increase	Yield	Incre'se	
					Grain, bushels						
1	31.88	.....	32.92	.....	30.35	.....	22.76	.....	22.83	.....	1
2	36.02	3.96	41.90	9.74	40.33	9.78	29.00	7.59	28.90	6.12	2
3	34.93	2 69	36.14	4.74	37.55	6.79	23.17	3.11	32.31	9.59	3
4	32.43	.....	30.64	.....	30.95	.....	18.69	.....	22.66	.....	4
5	35.38	2 33	36.24	5.75	37.37	6.01	23.77	4.77	31.79	8.10	5
6	43.32	9.65	47.61	17.26	46.95	15.17	35.09	15,77	39.43	14.72	6
7	34.29	.....	30.20	.....	32.17	.....	19.62	.....	25.74	.....	7
8	40.11	7.21	44.49	14.17	50.69	19.42	37.60	17.41	44.63	19.30	8
9	33.00	1.48	36.62	6.19	40.47	10.10	30.28	9.52	35.94	11.01	9
10	30.13	.....	30.55	.....	29.47	.....	21.33	.....	24.52	.....	10
11	41.28	10.72	49.90	19.45	54.13	24.04	41.37	20 90	46.34	21.72	11
12	41.07	10.09	52.18	21.82	52.88	22 14	41.20	21.58	46.87	22.16	12
13	31.41	.....	30.26	.....	31.38	.....	18.76	.....	24.81	.....	13
14	40.96	10 27	47.81	18.33	48.85	18.37	35.98	17.61	43.86	19.72	14
15	32.26	5.92	35.52	6.83	39.13	9.42	24.47	6.49	32.37	8.90	15
16	29.23	.....	27.91	.....	28.81	.....	17.59	.....	22.81	.....	16
17	35.78	6.59	49.54	20.48	53.91	23.87	44.10	25.88	46.23	22.84	17
18	40.73	10.04	49.52	19.32	59.75	28.48	55.83	37.24	55.24	31.26	18
19	33.12	.....	31.35	.....	32.49	.....	19.47	.....	24.57	.....	19
20	38.91	7.10	43.08	12 82	50.31	18.74	39.21	19.65	42.52	17.63	20
21	37.66	7.16	48.79	19.63	54.03	23.39	43.36	23.70	46.98	21.77	21
22	29.19	.....	28.06	.....	29.72	.....	19.75	.....	25.53	.....	22
23	37.68	7.71	49.51	19.90	53.53	23 16	43.17	22.57	47.29	21.24	23
24	40.51	9.75	49 44	18.27	53.11	22 08	42.81	21.36	46.93	20.37	24
25	31.54	.....	32.72	.....	31.68	.....	22.30	.....	27.07	.....	25
26	39.14	6.22	50.31	17.30	51 28	19.01	35.26	12.72	45.44	18.57	26
27	40.61	6.29	53.25	19.25	50.81	17.95	41.40	18.63	44.63	17.98	27
28	35.71	.....	33.58	.....	33.45	.....	23.01	.....	26.44	.....	28
29	43.89	8.19	53.36	19.77	50.75	17.30	38.71	15.70	43.52	17.08	29
30	41.73	6.02	46.51	12.93	54.87	21.42	45.85	22.84	43.93	17.49	30
*	31.89	.....	30.82	.....	31.04	.....	20.31	.....	24.70	.....	
†	38.75	6.97	46.09	15.23	49.03	17.83	37.58	17.25	42.26	17.38	
					Stover, pounds						
1	1,614	.....	1,574	.....	1,603	.....	1,597	.....	1,334	.....	1
2	1,622	3	1,828	287	2,223	401	1,707	151	1,528	198	2
3	1,696	73	1,824	315	2,251	410	1,807	292	1,670	344	3
4	1,628	.....	1,476	.....	1,860	.....	1,475	.....	1,322	.....	4
5	1,674	59	1,726	250	2,094	219	1,925	197	1,656	297	5
6	1,818	217	1,988	512	2,247	356	1,795	313	1,834	437	6
7	1,588	.....	1,476	.....	1,906	.....	1,485	.....	1,434	.....	7
8	1,832	285	2,046	585	2,668	784	2,025	523	2,012	587	8
9	1,666	161	1,774	329	2,274	411	1,972	454	1,810	393	9
10	1,466	.....	1,430	.....	1,842	.....	1,535	.....	1,408	.....	10
11	1,821	323	2,180	733	2,818	950	2,230	751	2,146	718	11
12	1,824	293	2,274	809	2,767	872	2,205	783	2,106	658	12
13	1,564	.....	1,482	.....	1,920	.....	1,365	.....	1,468	.....	13
14	1,924	340	2,166	691	2,533	632	1,995	632	1,980	530	14
15	1,690	138	1,696	229	2,164	282	1,675	315	1,666	234	15
16	1,622	.....	1,460	.....	1,862	.....	1,357	.....	1,414	.....	16
17	1,802	165	2,222	728	2,736	835	2,157	753	2,082	665	17
18	2,060	407	2,272	744	2,883	944	2.572	1,121	2,416	995	18
19	1,668	.....	1,562	.....	1,978	.....	1,497	.....	1,424	.....	19
20	1,930	300	2,016	489	2,576	599	2,052	541	1,972	538	20
21	1,884	292	2,162	669	2,715	739	2,162	637	2.088	644	21
22	1,554	.....	1,458	.....	1,975	.....	1,540	.....	1.454	.....	22
23	1,854	265	2,226	721	2.682	702	2,180	621	2,104	619	23
24	1,988	363	2,230	679	2,648	663	2,160	582	2,088	573	24
25	1,660	.....	1,598	.....	1,990	.....	1,597	.....	1,546	.....	25
26	2,010	314	2.256	628	2,692	683	2,067	486	2,128	591	26
27	1,946	214	2,386	728	2,588	560	2,190	624	2,034	507	27
28	1,768	.....	1,688	.....	2.047	.....	1,550	.....	1,518	.....	28
29	2,100	332	2 380	692	2,751	704	2,180	630	2,094	576	39
30	1,892	124	2.166	478	2,646	599	2,215	665	2,112	594	30
*	1,613	.....	1,520	.....	1 916	.....	1,501	.....	1,432	.....	
†	1,852	233	2,091	565	2,548	617	2,064	533	1,976	535	

*Average unfertilized yield.
†Average yield and increase from fertilizers.

TABLE VI.—Yield and increase per acre of OATS grown in 5-year rotation at Wooster. 25-year averages, 1894-1918

Plot No.	Fertilizing materials	Grain		Straw	
		Yield	Increase	Yield	Increase
	Pounds per acre	*Bu.*	*Bu.*	*Lb.*	*Lb.*
1	None	33.29	.....	1 394	.....
2	Acid phosphate, 80	42.09	9.44	1 757	395
3	Muriate potash, 80	35.44	3.43	1 461	130
4	None	31.37	.....	1,299	.....
5	Nitrate soda, 160	36.15	4.57	1,485	179
6	Acid phosphate, 80; nitrate soda, 160	48.15	16.37	2,039	726
7	None	31.99	.....	1,319	.....
8	Acid phosphate, 80; muriate potash, 80	44.96	13.03	1,971	672
9	Muriate potash, 80; nitrate soda, 160	38.33	6.45	1,680	402
10	None	31.82	.....	1 258	.....
11	Acid phosphate, 80; muriate potash, 80; nitrate soda, 160	51.24	19.32	2,355	1,065
12	Acid phosphate, 80; muriate potash, 80; nitrate soda, 240	50.73	18.70	2,374	1,051
13	None	32.13	.....	1,355	.....
14	Fertilized on corn and wheat only	40.98	9.41	1,753	437
15	Fertilized on wheat only	34.19	3.97	1,425	157
16	None	30.44	.....	1,237	.....
17	Acid phosphate, 160; muriate potash, 80; nitrate soda, 80	51.12	20.15	2,456	1,186
18	Manured on corn and wheat	46.61	13.02	2,091	783
19	None	32.05	.....	1,337	.....
20	Manured on corn and wheat	39.52	7.74	1,719	402
21	Same elements as 17, but nitrogen in oilmeal	49.68	18.09	2,263	950
22	None	31.25	.....	1,279	.....
23	Same elements as 17, but nitrogen in dried blood	49.82	18.16	2,264	956
24	Same elements as 17, but nitrogen in sulphate ammonia	51.04	18.96	2,424	1,087
25	None	32.49	.....	1,366	.....
26	Same elements as 11, but phosphorus in bonemeal	48.43	15.46	2,155	792
27	Same elements as 17, but nitrogen in nitrate of lime	51.04	17.58	2,359	999
28	None	33.95	.....	1,358	.....
29	Same elements as 11, but phosphorus in basic slag	49.23	15.28	2,194	836
30	Same elements as 17, but nitrogen in tankage	47.68	13.74	2,121	763
	Average unfertilized yield	32.08	.....	1 321	.....
	Average increase from fertilizers	.....	13.14	.....	698

Note: During the first 5 years the quantities of elements on Plots 17, 21, 23 and 24 were the same as on Plot 11, and those of nitrogen and potassium on Plot 30 were smaller. Previous to 1910 Plot 27 received the same quantities of elements as Plot 11, with nitrogen in nitrate of soda and phosphorus in dissolved boneblack.

TABLE VII.—Yield and increase per acre of OATS grown in 5-year rotation at Wooster. 5-year averages

Plot No.	5 yrs., 1894–1898		5 yrs., 1899–1903		5 yrs., 1904–1908		5 yrs., 1909–1913		5 yrs., 1914–1918		Plot No.
	Yield	Increase	Yield	Increase	Yield	Increase	Yield	Increase	Yield	Incre'se	
					Grain, bushels						
1	32 20	.....	28.32	.....	37.25	.....	27.19	.....	41.50	.....	1
2	37.63	534	37.37	8.66	45.72	9.91	37.67	11.26	52.04	12.00	2
3	34.71	232	33.70	4.62	38.34	3.97	28.45	2.83	41.98	3.39	3
4	32.48	.....	29.47	.....	32.94	.....	24.84	.....	37.14	.....	4
5	35.40	311	34.89	5 95	36.80	3.50	29.08	3.49	44.58	6.80	5
6	40.36	826	48.75	20.32	50.41	16.75	42.63	16.29	58.62	20.20	6
7	31.90	.....	27.90	.....	34.02	.....	27.08	.....	39.06	.....	7
8	38.26	687	40 92	12.72	48.89	14.34	42.34	16.16	54.40	15.04	8
9	33.36	246	35.75	7.26	39.60	4.53	35.50	10.22	47.45	7.80	9
10	30.39	.....	28.78	.....	35.60	.....	24.39	.....	39.95	.....	10
11	43.61	12.92	52.48	23.74	53.49	18.65	45.61	20.72	61.03	20.87	11
12	45.11	14.11	52.37	23.65	49.16	14.49	46.77	21.38	60.23	19.86	12
13	31.30	.....	28.68	.....	34.22	.....	25.89	.....	40 58	.....	13
14	36.79	619	37.18	9.23	42.69	8.95	36.37	10.68	51 84	11.97	14
15	30.31	.....	30.25	3.51	36.46	3.19	29.72	4.23	44.20	5.04	15
16	29.20	.....	26.50	.....	32.79	.....	25.28	.....	38.45	.....	16
17	38.03	8.57	49.19	22.21	54.97	21.68	49.59	23.62	63.92	24.64	17
18	36.91	5.20	40.36	12.90	46.71	12.93	41.94	15.43	57.19	17.07	18
19	29.97	.....	27.93	.....	34.27	.....	27.12	.....	40.95	.....	19
20	32.39	2.58	36.45	9.05	42.00	7.90	36.34	9.39	50.42	9.76	20
21	37.43	7.78	50.64	24.51	52.87	18.93	46.97	20.20	60.70	20.34	21
22	29.50	.....	26.33	.....	33.76	.....	26.60	.....	40.08	.....	22
23	39.81	9.94	48.67	21.75	52.06	17.78	47.42	20 63	61.15	20.69	23
24	43.01	12.76	49.29	21.79	52.52	17.73	47.50	20.51	62.87	22.01	24
25	30.62	.....	28.09	.....	35.30	.....	27.19	.....	41.25	.....	25
26	43.04	12.11	47.11	18.00	49.98	14.82	42.65	15.02	59.39	17.34	26
27	43.54	12.29	51.59	21.48	52.91	17.89	44.76	16.68	62.41	19.57	27
28	31.56	.....	31.12	.....	34.87	.....	28.53	.....	43.64	.....	28
29	42.49	10.93	49.19	18.08	50.58	15.70	42.50	13.97	61.39	17.75	29
30	35.47	3.91	45.78	14.65	49.83	14.96	45.51	16.98	61.83	18.19	30
*	30.91	.....	28.31	.....	34.50	.....	26.41	.....	40.25	.....	
†	38.38	7.77	43.90	15.20	47.30	12.91	40.96	14.48	55.88	15.52	
					Straw, pounds						
1	1,233	.....	1,120	.....	1,588	.....	1,312	.....	1,718	.....	1
2	1,341	83	1,452	345	1,949	414	1,850	568	2,212	563	2
3	1,287	3	1,211	117	1,660	177	1,347	135	1,799	219	3
4	1,309	.....	1,080	.....	1,430	.....	1,163	.....	1,511	.....	4
5	1,315	35	1,337	285	1,590	144	1,328	129	1,853	303	5
6	1,549	298	1 778	752	2,215	752	2,155	921	2,496	909	6
7	1,221	.....	998	.....	1,479	.....	1,269	.....	1,630	.....	7
8	1,479	278	1,514	525	2,236	733	2,165	926	2,459	898	8
9	1,290	113	1,336	355	1,830	304	1,968	761	1,970	477	9
10	1,167	.....	973	.....	1,550	.....	1,175	.....	1,423	.....	10
11	1,809	609	1,989	993	2,228	1,101	2,424	1 220	2,885	1,398	11
12	1,952	721	2,220	1,202	2,516	933	2,529	1,298	2,651	1,101	12
13	1,263	.....	1,040	.....	1,599	.....	1,259	.....	1,613	.....	13
14	1,524	298	1,420	410	2,008	481	1,682	447	2,129	555	14
15	1,138	.....	1,098	152	1,667	199	1,340	129	1,683	149	15
16	1,151	.....	948	.....	1,402	.....	1,187	.....	1,495	.....	16
17	1,552	410	1,996	1,020	2,829	1,360	2,807	1,575	3,096	1,564	17
18	1,444	349	1,636	636	2,431	996	2,280	1,002	2,530	962	18
19	1,127	.....	1,026	.....	1,602	.....	1,324	.....	1,605	.....	19
20	1,315	174	1,355	366	2,010	444	1,835	514	2,079	510	20
21	1,560	404	2,057	1,103	2,580	1,049	2,410	1,093	2,664	1,130	21
22	1,170	.....	918	.....	1,493	.....	1 314	.....	1,498	.....	22
23	1,434	223	1,993	1,030	2,598	1,073	2,476	1,130	2,817	1,323	23
24	1,791	540	2,140	1,134	2,729	1,170	2,702	1,323	2,758	1,269	24
25	1,292	.....	1,051	.....	1,592	.....	1,412	.....	1,485	.....	25
26	1,604	341	1,905	837	2,402	840	2,265	854	2,601	1,086	26
27	1,724	490	2,035	952	2,729	1,200	2,581	1,170	2,727	1,182	27
28	1,206	.....	1 100	.....	1,497	.....	1,411	.....	1 575	.....	28
29	1,678	472	1,850	750	2,507	1,011	2,072	661	2,863	1,288	29
30	1 343	137	1,739	639	2,427	930	2,397	986	2.699	1,124	30
*	1,214	.....	1,025	.....	1,523	.....	1,283	.....	1,556	.....	
†	1,507	299	1,703	655	2,257	761	2,130	842	2,449	885	

*Average unfertilized yield.

†Average yield and increase from fertilizers.

TABLE VIII.—Yield and increase per acre of WHEAT grown in 5-year rotation at Wooster: 25-year averages, 1894-1918

Plot	Fertilizing materials	Grain		Straw	
		Yield	Increase	Yield	Increase
	Pounds per acre	*Bu.*	*Bu.*	*Lb.*	*Lb.*
1	None	11.77	.....	1,210	.....
2	Acid phosphate, 160	19.63	7.97	1,934	746
3	Muriate potash, 100	12.66	1.11	1,312	146
4	None	11.44	.....	1,145	.....
5	Dried blood, 50; nitrate soda, 120	13.39	1.85	1,471	316
6	Acid phosphate, 160; dried blood, 50; nitrate soda, 120	25.37	13.75	2,590	1,425
7	None	11.71	.....	1,174	.....
8	Acid phosphate, 160; muriate potash, 100	20.98	9.31	2,029	868
9	Muriate potash, 100; dried blood, 50; nitrate soda, 120	14.37	2.75	1,502	354
10	None	11.57	.....	1,134	.....
11	Acid phos., 160; mur. potash, 100; dried blood; 50; nit. soda, 120	28.12	16.58	2,996	1,861
12	Acid phos., 160; mur. potash, 100; dried blood, 50; nit. soda, 200	28.88	17.37	3,089	1,954
13	None	11.47	.....	1,136	.....
14	Acid phos., 160; mur. potash, 100; dried blood, 50; nit. soda, 120	26.10	14.98	2,720	1,617
15	Acid phos., 160; mur. potash, 100; dried blood, 50; nit. soda, 120	25.14	14.38	2,592	1,523
16	None	10.41	.....	1,035	.....
17	Acid phos., 160; mur. potash, 100, dried blood, 25; nit. soda, 60.	24.30	13.55	2,506	1,424
18	Barnyard manure, 8 tons	24.16	13.07	2,630	1,501
19	None	11.41	.....	1,176	.....
20	Barnyard manure, 4 tons	19.69	8.41	2,054	907
21	Same elements as 17, but nitrogen in oilmeal	24.43	13.30	2,544	1,424
22	None	11.00	.....	1,092	.....
23	Same elements as 17, but nitrogen in dried blood	23.50	12.23	2,407	1,273
24	Same elements as 17, but nitrogen in sulphate ammonia	24.27	12.72	2,484	1,309
25	None	11.82	.....	1,216	.....
26	Same elements as 11, but phosphorus in bonemeal	24.51	12.79	2,526	1,336
27	Same elements as 17, but nitrogen in nitrate of lime	26.49	14.86	2,727	1,563
28	None	11.53	.....	1,138	.....
29	Same elements as 11, but phosphorus in basic slag	25.88	14.35	2,720	1 582
30	Same elements as 17, but nitrogen in tankage	23.41	11.88	2,346	1,208
	Average unfertilized yield	11.43	.....	1.147	.....
	Average yield and increase from fertilizers	22.76	11.33	2 359	1,212

Note: Plot 14 is fertilized on corn and wheat only, and Plot 15 on wheat only. During the first 5 years the quantities of elements on Plots 17, 21, 23 and 24 were the same as on Plot 11, and those of nitrogen and potassium on Plot 30 were smaller. Previous to 1910 Plot 27 received the same quantities of elements as Plot 11.

TABLE IX.—Yield and increase of WHEAT grown in 5-year rotation at Wooster. 5-year averages

Plot No.	5 yrs., 1894-1898		5 yrs., 1899-1903		5 yrs., 1904-1908		5 yrs., 1909-1913		5 yrs., 1914-1918		Plot No.
	Yield	Increase	Yield	Increase	Yield	Increase	Yield	Increase	Yield	Increase	
					Grain, bushels						
1	8.79	.....	9 03	.....	13.43	.....	12.62	.....	15.01	.....	1
2	12.35	3.14	18.67	9.81	24.13	10.54	19.06	6.81	23.97	9.95	2
3	11.26	1.64	9.54	.86	15.11	1.37	12.04	.16	15.35	1.51	3
4	10.03	.....	8.50	.....	13.90	.....	11.51	.....	13.26	.....	4
5	11.57	1.54	10.58	2.10	16.16	2.23	13.02	1.63	15.60	1.76	5
6	16.84	6.81	24.46	16.00	30.87	16.92	24.21	12.94	30.48	16.07	6
7	10.02	.....	8.45	.....	13.97	.....	11.15	.....	14.98	.....	7
8	15.20	5.22	19.78	11.31	23.96	10.06	19.81	8.45	26.12	11.50	8
9	12.09	2.15	11.12	2.61	17.31	3.48	14.01	2.45	17.33	3.07	9
10	9.89	.....	8.53	.....	13.76	.....	11.77	.....	13.91	.....	10
11	20.53	10.73	27.47	18.82	33.10	19.32	26.43	14.86	33.06	19.18	11
12	20.95	11.23	29.37	20.61	33.58	19.77	26.27	14.90	34.21	20.35	12
13	9.63	.....	8.88	.....	13.84	.....	11.18	.....	13.83	.....	13
14	18.11	8.92	25.55	17.10	32.10	18.65	23.91	13.07	30.85	17.18	14
15	16.77	8.04	24.80	16.80	30.46	17.39	23.18	12.66	30.50	16.98	15
16	8.28	.....	7.57	.....	12.68	.....	10.17	.....	13.37	.....	16
17	13.84	5.55	23.20	15.39	29.28	16.11	23.51	12.97	31.66	17.74	17
18	12.65	4.35	19.02	10.97	29.97	16.29	26.67	15.78	32.47	17.98	18
19	8.31	.....	8.28	.....	14.18	.....	11.26	.....	15.05	.....	19
20	11.48	3.25	14.67	6.41	24.47	10.52	21.99	10.87	25.83	10.99	20
21	18.35	10.20	23.88	15.66	27.95	14.24	22.98	11.99	29.02	14.40	21
22	8.07	.....	8.20	.....	13.49	.....	10.86	.....	14.40	.....	22
23	16.78	8.14	23.28	14.71	26.47	12.95	22.44	11.38	28.54	13.97	23
24	17.85	8.64	22.97	14.02	27.48	13.93	23.25	11.98	29.80	15.05	24
25	9.78	.....	9.32	.....	13.60	.....	11.48	.....	14.93	.....	25
26	18.17	8.33	24.18	15.07	28.12	14 66	23.13	11.70	28.95	14.18	26
27	18.86	8.94	28.72	19.81	31.53	18.20	23.41	12.02	29.93	15.33	27
28	9.98	.....	8.70	.....	13.20	.....	11.34	.....	14.45	.....	28
29	18.71	8.73	26.58	17.88	28.54	15.34	23.51	12.17	32.07	17.62	29
30	14.66	4.68	23.90	15.20	27.35	14.15	21.84	10.50	29.33	14.88	30
*	9.28	.....	8.55	.....	13.60	.....	11.33	.....	14.32	.....	
†	15.85	6.51	21.59	13.06	26.90	13.31	21.73	10.46	27.75	13.46	
					Straw, pounds						
1	944	.....	898	.....	1,542	.....	1,161	.....	1 506	.....	1
2	1,417	426	1.756	889	2,382	866	1,891	754	2,227	795	2
3	1,226	189	913	76	1 687	198	1,247	133	1,489	132	3
4	1,084	.....	807	.....	1,462	.....	1,090	.....	1,282	.....	4
5	1,327	223	1.018	216	1,918	464	1,478	378	1,614	299	5
6	2,007	893	2,276	1,473	3,084	1,638	2,612	1,502	2,969	1 620	6
7	1,130	.....	801	.....	1,438	.....	1,120	.....	1,382	.....	7
8	1,559	465	1,799	999	2,216	795	2,057	940	2,512	1,139	8
9	1,269	211	1,106	306	1 945	542	1,436	323	1,754	390	9
10	1,022	.....	799	.....	1,386	.....	1,109	.....	1,355	.....	10
11	2,356	1 331	2.676	1,880	3,505	2,086	3,017	1,925	3,424	2,081	11
12	2,433	1,406	2,702	1,910	3,651	2,199	3,041	1,967	3,620	2,288	12
13	1,030	.....	789	.....	1,485	.....	1,057	.....	1,320	.....	13
14	2,175	1.196	2,461	1,702	3,263	1,857	2,633	1,592	3,067	1,739	14
15	1,943	1,015	2,338	1,609	3,078	1,752	2,530	1.506	3,070	1 734	15
16	877	.....	699	.....	1,247	.....	1,008	.....	1,344	.....	16
17	1,545	680	2,162	1,439	2,927	1,585	2,584	1,529	3,310	1,885	17
18	1,579	724	1,973	1,227	3,047	1,610	3 012	1,913	3,540	2,034	18
19	843	.....	771	.....	1,532	.....	1,148	.....	1,587	.....	19
20	1,359	511	1.564	804	2,503	1,027	2,243	1,108	2,598	1,076	20
21	2,119	1,266	2,261	1,513	2,841	1,421	2,500	1,377	2,999	1,542	21
22	858	.....	737	.....	1,364	.....	1,110	.....	1,392	.....	22
23	1,813	908	2,201	1,428	2,546	1,122	2,438	1,296	3,035	1,612	23
24	1.917	965	2,156	1,347	2,719	1.234	2,551	1,376	3,080	1,625	24
25	999	.....	845	.....	1,544	.....	1,207	.....	1,486	.....	25
26	2.085	1,088	2,197	1,376	2,834	1,389	2,593	1,384	2,921	1,450	26
27	2,120	1,124	2,631	1,837	3,168	1,807	2,694	1,482	3,020	1,564	27
28	995	.....	770	.....	1,270	.....	1,214	.....	1,441	.....	28
29	2,095	1,100	2,401	1,631	3,057	1,787	2,571	1,357	3,476	2,035	29
30	1,580	585	1,998	1,228	2,779	1,510	2 365	1,151	3,007	1,566	30
*	979	.....	791	.....	1,437	.....	1,122	.....	1,410	.....	
†	1,796	816	2,029	1,244	2,757	1,344	2,375	1,249	2,837	1,430	

*Average unfertilized yield.

†Average yield and increase from fertilizers.

TABLE X.—Yield and increase per acre of CLOVER and TIMOTHY grown in 5-year rotation at Wooster, for the entire period of the experiment

Plot	Total quantities of fertilizing materials applied to previous crops of the rotation. None on clover or timothy	23-year av. Clover		21-year av. Timothy	
		Yield	Increase	Yield	Increase
	Pounds per acre	*Lb.*	*Lb.*	*Lb.*	*Lb.*
1	None	1 778	.....	2 754	.....
2	Acid phosphate, 320	2,234	478	3 061	350
3	Muriate potash, 260	1 944	211	2,798	130
4	None	1,711	.....	2,626	.....
5	Nitrate soda, 440; dried blood, 50	2,081	381	2,968	373
6	Acid phosphate, 320; nitrate soda, 440; dried blood, 50	2,831	1 143	3,383	820
7	None	1,677	.....	2 532	.....
8	Acid phosphate, 320; muriate potash, 260	2,590	941	3 077	571
9	Muriate potash, 260; nitrate soda, 440; dried blood, 50	2,036	416	2,815	334
10	None	1,592	.....	2,456	.....
11	Acid phos., 320; mur. potash, 260; nit. soda, 440; dried blood, 50	2,983	1,379	3,450	996
12	Acid phos., 320; mur. potash, 260; nit. soda, 680; dried blood, 50	3,090	1,471	3,408	950
13	None	1 633	.....	2,466	.....
14	Acid phos., 240; mur. potash, 180; nit. soda, 280; dried blood, 50	2,575	989	3 044	600
15	Acid phos., 160; mur. potash, 100; nit. soda, 120; dried blood, 50	2 251	713	2,813	391
16	None	1,491	.....	2,401	.....
17	Acid phos., 480; mur. potash, 260; nit. soda, 220; dried blood, 25	2,868	1,328	3 326	872
18	Yard manure, 16 tons	3 690	2 101	4 146	1,640
19	None	1,637	.....	2,559	.....
20	Yard manure, 8 tons	2,682	1,111	3,427	956
21	Same elements as 17, but nitrogen in oilmeal	2,607	1,103	3,082	699
22	None	1,437	.....	2 294	.....
23	lements as 17, but nitrogen in dried blood	2,570	1,054	3,067	669
24	Same elements as 17, but nitrogen in sulphate ammonia	2,692	1,098	3,101	598
25	None	1,673	.....	2,607	.....
26	Same elements as 11, but phosphorus in bonemeal	3,100	1,416	3 558	908
27	Same elements as 17, but nitrogen in nitrate of lime	2,730	1,033	3,359	665
28	None	1,709	.....	2,737	.....
29	Same elements as 11, but phosphorus in basic slag	3,012	1,303	3 644	907
30	Same elements as 17, but nitrogen in tankage	2,991	1,282	3,716	979
	Average unfertilized yield	1,634	.....	2,545	.....
	Average yield and increase from fertilizers	2 678	1,047	3 262	717

Note: During the first 5 years the quantities of elements on Plots 17, 21, 23 and 24 were the same as on Plot 11, and those of nitrogen and potassium on Plot 30 were smaller. Previous to 1910 Plot 27 received the same quantities of elements as Plot 11.

TABLE XI: Yield and increase per acre of CLOVER and TIMOTHY grown in 5-year rotation at Wooster. 5-year averages.

Plot No.	5 yrs., 1895-1899		5 yrs., 1900-1904		5 yrs., 1905-1909		5 yrs., 1910-1914		4 yrs., 1915-1918		Plot No.
	Yield	Increase	Yield	Increase	Yield	Increase	Yield	Increase	Yield	Increase	
Clover											
	Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	
1	1,650	.....	1,759	.....	2,737	.....	1,467	.....	1,147	.....	1
2	2,120	387	2,018	273	3,621	925	1,739	360	1,471	387	2
3	1,934	117	1,768	36	3,279	613	1,408	118	1,136	116	3
4	1,900	.....	1,718	.....	2,631	.....	1,202	.....	957	.....	4
5	1,984	100	2,130	489	3,085	481	1,619	395	1,477	484	5
6	2,798	930	2,397	834	4,155	1,578	2,357	1,109	2,244	1,214	6
7	1,852	.....	1,485	.....	2,550	.....	1,271	.....	1,066	.....	7
8	2,574	690	1,909	420	4,142	1,683	2,183	948	1,858	838	8
9	2,258	342	1,857	365	2,908	541	1,618	419	1,373	398	9
10	1,948	.....	1,495	.....	2,275	.....	1,163	.....	929	.....	10
11	2,952	989	2,613	1,165	4,379	2,040	2,474	1,309	2,294	1,342	11
12	3,076	1,097	2,663	1,264	4,507	2,104	2,570	1,402	2,414	1,439	12
13	1,992	.....	1,352	.....	2,467	.....	1,172	.....	998	.....	13
14	2,858	944	2,201	886	3,795	1,412	1,998	846	1,790	800	14
15	2,400	564	1,797	524	3,387	1,087	1,874	740	1,572	590	15
16	1,758	.....	1,237	.....	2,215	.....	1,115	.....	974	.....	16
17	2,536	745	2,221	927	4,351	2,084	2,544	1,389	2,481	1,440	17
18	3,075	1,237	2,870	1,518	5,345	3,027	3,480	2,283	3,488	2,380	18
19	1,856	.....	1,411	.....	2,370	.....	1,237	.....	1,175	.....	19
20	2,556	761	2,200	855	3,906	1,664	2,320	1,095	2,242	1,134	20
21	2,526	793	1,910	631	3,997	1,882	2,286	1,073	2,067	1,025	21
22	1,672	.....	1,212	.....	1,987	.....	1,202	.....	975	.....	22
23	2,518	779	1,894	610	3,769	1,638	2,434	1,174	1,980	962	23
24	2,486	679	1,946	590	4,255	1,980	2,457	1,139	2,033	973	24
25	1,874	.....	1,428	.....	2,420	.....	1,376	.....	1,103	.....	25
26	2,686	842	2,746	1,250	4,871	2,408	2,695	1,333	2,266	1,160	26
27	2,424	610	2,343	778	4,344	1,837	2,371	1,024	1,932	824	27
28	1,784	.....	1,632	.....	2,550	.....	1,333	.....	1,111	.....	28
29	2,512	728	2,737	1,105	4,316	1,795	2,841	1,508	2,458	1,347	29
30	2,460	676	2,366	733	4,739	2,188	2,837	1,504	2,287	1,176	30
*	1,829	.....	1,473	.....	2,420	.....	1,253	.....	1,043	.....	
†	2,620	787	2,286	872	4,245	1,888	2,305	1,058	2,043	1,000	
Timothy											
1	2,714	.....	2,844	.....	3,317	.....	2,473	.....	2,291	.....	1
2	2,882	186	2,802	67	3,944	637	3,066	602	2,605	374	2
3	3,014	336	2,600	—28	3,384	87	2,617	162	2,230	60	3
4	2,660	.....	2,517	.....	3,286	.....	2,446	.....	2,110	.....	4
5	2,842	213	2,894	449	3,951	689	2,651	228	2,411	283	5
6	3,116	517	3,156	786	4,448	1,211	3,246	847	2,970	825	6
7	2,568	.....	2,300	.....	3,213	.....	2,375	.....	2,163	.....	7
8	2,850	337	2,740	441	3,984	740	3,146	849	2,716	577	8
9	2,682	225	2,801	501	3,649	373	2,511	293	2,354	240	9
10	2,402	.....	2,300	.....	3,307	.....	2,140	.....	2,090	.....	10
11	3,246	819	3,311	960	4,609	1,382	3,049	907	3,013	918	11
12	2,942	491	3,361	959	4,578	1,432	3,171	1,028	3,019	920	12
13	2,476	.....	2,450	.....	3,064	.....	2,144	.....	2,104	.....	13
14	3,082	623	2,966	609	3,960	908	2,622	441	2,453	348	14
15	2,846	405	2,626	362	3,626	588	2,520	301	2,378	273	15
16	2,424	.....	2,172	.....	3,025	.....	2,255	.....	2,106	.....	16
17	2,898	445	2,748	549	4,466	1,371	3,557	1,225	3,171	986	17
18	3,520	1,037	3,430	1,204	5,463	2,297	4,718	2,308	3,867	1,604	18
19	2,512	.....	2,252	.....	3,237	.....	2,486	.....	2,342	.....	19
20	3,082	655	2,908	747	4,764	1,610	3,580	1,216	2,877	585	20
21	2,790	447	2,662	593	4,171	1,099	3,271	1,028	2,564	323	21
22	2,258	.....	1,977	.....	2,988	.....	2,120	.....	2,191	.....	22
23	2,824	467	2,593	534	4,142	1,013	3,131	892	2,746	472	23
24	2,784	327	2,604	463	3,935	667	3,344	988	3,022	666	24
25	2,556	.....	2,222	.....	3,408	.....	2,475	.....	2,439	.....	25
26	3,358	709	3,200	913	4,857	1,383	3,273	826	3,136	708	26
27	3,268	525	3,005	653	4,584	1,044	3,097	677	2,813	395	27
28	2,836	.....	2,416	.....	3,605	.....	2,393	.....	2,407	.....	28
29	3,686	850	3,378	962	4,797	1,192	3,400	1,007	2,803	396	29
30	3,538	702	3,232	816	4,866	1,260	3,930	1,536	3,000	593	30
*	2,541	.....	2,345	.....	3,245	.....	2,331	.....	2,241	.....	
†	3,105	567	2,974	968	4,383	1,112	3,195	867	2,807	566	

*Average unfertilized yields. †Average yield and increase from fertilizers.

TABLE XII.—THE 5-YEAR ROTATION AT WOOSTER. Total fertilizing materials and their cost, and total and net value of increase produced for 5-year periods and for 25 years, all calculated for one rotation of 5 years

Plot No.	Fertilizing materials for each rotation Pounds per acre					Average value of total increase per acre for for each rotation						Net gain or loss (—) per acre from fertilizers for each rotation						Plot No.
	Acid phosphate	Muriate of potash	Nitrate of soda	Dried blood	Cost	First 5 yrs.	Second 5 yrs.	Third 5 yrs.	Fourth 5 yrs.	Fifth 5 yrs.	Whole period	First 5 yrs.	Second 5 yrs.	Third 5 yrs.	Fourth 5 yrs.	Fifth 5 yrs.	Whole period	
2	320	.....	.....	.....	$2.60	$8.50	$17.37	$24.32	$17.18	$18.59	$16.95	$5.90	$14 77	$21.72	$14 58	$15.99	$14.35	2
3	.....	260	.....	.....	6.50	5.19	4.67	9.17	4.07	7.63	6.17	— 1.31	—1.83	2.67	—2.43	1.13	— .33	3
5	.....	.....	440	50	14.40	4.70	10.47	9.30	7.55	10.80	8.84	— 9.70	—3.93	—5.10	—6.85	—3.60	—5.56	5
6	320	.....	440	50	17.00	19.09	35.27	39.75	32.26	36.14	32.25	2.09	18.27	22.75	15.26	19.14	15.25	6
8	320	260	.....	.....	9.10	14.40	24.37	33.51	28.41	30 01	25.94	5.30	15.27	24.41	19.31	20.91	16.84	8
9	.....	260	440	50	20.90	5.85	11.35	13.23	13.45	13.20	11.44	—15.05	—9.55	—7.67	—7.45	—7.70	—9.46	9
11	320	260	440	50	23.50	26.39	42.43	49.96	39 60	43.89	40.24	2.89	18.93	26.46	16.10	20.39	16.74	11
12	320	260	680	50	30.70	26.16	45.53	48.24	41.12	44.91	41.00	— 4.54	14.83	17.54	10.42	14.21	10.30	12
14	240	180	280	50	16.05	21.37	32.91	37.33	28.84	32.90	31.99	5.32	16.86	21.28	12.79	16.85	15.94	14
15	160	100	120	50	8.60	13.89	22.86	27.13	20.25	24.74	22.28	5.29	14.26	18.53	11 65	16.14	13.68	15
17	480	260	220	25	17.60	15.74	36.61	46.28	42.50	44.85	37.37	— 1.86	19.01	28.68	24.90	27.25	19.77	17
18	Yard manure, 16 tons.....				?	19.82	34.24	55.94	55.11	44 43	43.07	?	?	?	?	?	?	18
20	Yard manure, 8 tons.....				?	13.02	21.28	35.36	31.05	28.04	25.36	?	?	?	?	?	?	20
21	Same as 17, but nitrogen in oilmeal.....				17.60	20.43	36.25	42.24	37.86	35.36	34.12	2.83	18.65	24.64	20.26	17.76	16 52	21
23	Same as 17, all nitrogen in dried blood.....				17.60	19.09	34.37	39.28	35.94	35.48	32.73	1.49	16.77	21.68	18.34	17.88	15.13	23
24	Same as 17, nitrogen in sulphate ammonia..				17.60	20.70	32.77	38.71	36.36	37.10	33.20	3.10	15 17	21.11	18.76	19.50	15 60	24
26	Same as 11, phosphorus in bonemeal				23.50	20.89	36.17	42.55	30.56	34.87	33.05	— 2.61	12.67	19 05	7.06	11.37	9.55	26
27	Same as 17, nitrogen in nitrate of lime*.....				17.60	19.86	39.88	42.08	32.46	33.71	33.72	— 3.64	16.38	18.58	13.70	16.11	11.10	27
29	Same as 11, phosphorus in basic slag				23.50	21.91	39.32	39.04	33.23	37.41	34.44	— 1.51	15.82	15.54	9.73	13.91	10.94	29
30	Same as 17, nitrogen in tankage†.....				17.60	13.74	30.51	41.62	37.92	35.02	31.71	.....	12.91	24.02	20.32	17.42	.....	30

The nearest practicable approach to a common denominator for the various kinds of produce grown in this rotation is their market value, and in Table XII the results of the tests are arranged on this basis for five 5-year periods and for the entire 25 years, corn being rated at 40 cents per bushel, oats at 30 cents, wheat at 80 cents, hay at $8 per ton, stover at $3 and straw at $2; valuations much below present prices but not far from the average values during the first twenty years of the test. The low valuations serve for comparative purposes and it seems best not to change them until prices have become stabilized again.

The fertilizing materials are valued at a fraction over $16 per ton for acid phosphate, 2½ cents per pound for muriate of potash and 3 cents per pound for nitrate of soda; and it is assumed that the cost per pound of the fertilizing elements will be practically the same in the other carriers used on Plots 21 to 30, inclusive.

The table shows that the effectiveness of the fertilizers and manure increased during the first three periods, the greatest relative increase being shown by the manure. Taking the second part of the table, giving the net gain after deducting the cost of the fertilizers, it will be seen that during the first period eight of the fertilizer applications failed to produce sufficient increase to cover their cost; during the second and fourth periods three, during the third and fifth periods two, during the whole period three. Whenever either nitrate of soda or muriate of potash has been used unaccompanied by some carrier of phosphorus there has been a loss in each period (except from muriate of potash in the third period) and in the average of the 25 years.

Nevertheless, both nitrogen and potassium are essential to the highest net profit, as shown by comparing Plot 2, receiving phosphorus only, with Plot 6 receiving nitrogen, Plot 8 receiving potassium, and Plot 11 receiving both these elements in addition to phosphorus.

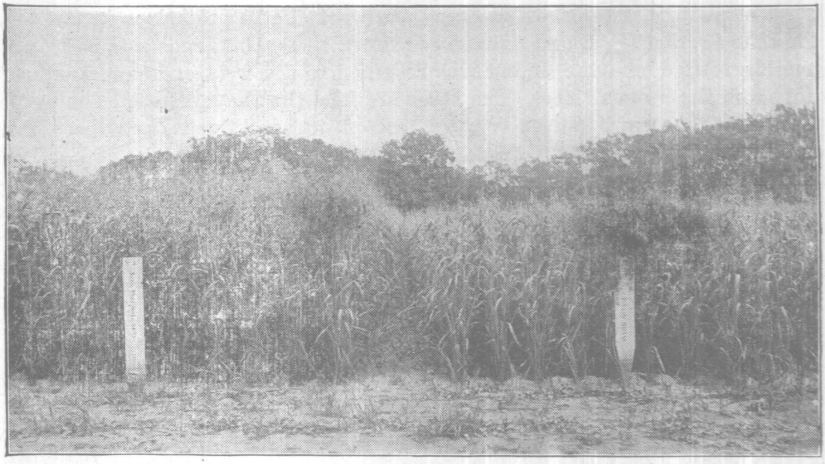
The results of the comparison of different carriers of nitrogen and phosphorus have been discussed in Circular No. 93.

*Since 1910; previously, same quantities of elements as on Plot 11, with nitrogen in nitrate of soda and phosphorus in dissolved boneblack.

†Since first period. Smaller applications during first period.

Plot 18: Manure on corn and wheat
25-year average yield,
45.8 bu. per acre

Plot 19: No treatment
25-year average yield,
35.9 bu. per acre



Eighty pounds of acid phosphate produced this difference in oats between the plot at the left and the other treated with an equal quantity of muriate of potash

III: LIMING THE LAND

The surface rocks underlying the farm on which the Wooster experiments are located, and also a large part of the eastern half of Ohio, are the sandstones and shales of the Waverly geological formation. At the Experiment Station and for a considerable distance southward the soil has been modified by glacial action, but as the movement of the glacier was generally parallel to the lines of rock outcrop the resultant soil has been derived chiefly from rocks similar in composition to those upon which the soil now rests.

The soil in the vicinity of the Experiment Station has been classed as Wooster silt loam; it resembles Volusia silt loam, but is better drained than the Volusia soils because of the more open character of the floor upon which it lies. It is medium in texture between a clay loam and a sandy loam, is easily worked and responsive to treatment and when first brought under cultivation produces good crops. It is, however, relatively deficient both in phosphorus and calcium, and under the exhaustive system of husbandry which has prevailed it has become so reduced in both elements that additions must be made before profitable crops can be grown.

At the time the experiments described on the preceding pages were planned the deficiency in calcium had not been detected, as clover was growing luxuriantly when other fertilizing elements were furnished, but within a few years the clover crops began to fail and in 1900 the experiment was begun of liming half the land as it was being prepared for corn, caustic lime being applied to the west ends of the plots, fertilized and unfertilized alike. The liming was begun on Section E and was continued on the west ends as the other four sections came under corn, when it was transferred to the east ends in order to make sure that the differences observed were not due to variations in the soil. By the time Sections E, B and A had been limed on the east ends this point was thoroughly settled, and the liming was returned to the west ends and has been continued on those ends since. The three sections that have had one liming on the east ends, however, still show the effect of that treatment, and the differences between the two ends on those sections are much smaller than on Sections C and D, which have never been limed on the east ends. The tables which follow, therefore, show a smaller effect from the liming than that which has actually resulted.

Tables XIII to XVI give the yields in the 5-year rotation for each crop for the period since the liming was begun.

Beginning with 1900, the corn yields on the limed and unlimed land have been harvested separately to date. The oats crops of 1902, 1903 and 1904 were not harvested separately. The wheat and timothy crops were not harvested separately until 1906, but the clover crops have been harvested separately since they first came under the effect of the liming, in 1903.

TABLE XIII.—Effect on CORN of liming the land. Yield and increase per acre, 1900-1918. (For fertilizer treatment see Table IV.)

Plot No.	Total yield				Increase from fertilizers				Gain for lime		Plot No.
	Grain		Stover		Grain		Stover		Grain	Stover	
	Unlimed	Limed	Unlimed	Limed	Unlimed	Limed	Unlimed	Limed			
	Bu.	*Bu.*	*Lb.*	*Lb.*	*Bu.*	*Bu.*	*Lb.*	*Lb.*	*Bu.*	*Lb.*	
1	25.44	31.39	1,559	1,698	.....	.....	.....	.....	5.95	139	1
2	33.94	39.37	1,795	1,983	8 60	8.37	237	298	5.43	188	2
3	31.17	38.47	1,899	2,058	5.94	7.86	341	383	7.30	159	3
4	25.11	30.22	1,558	1,663	.....	.....	.....	.....	5.11	105	4
5	31.67	37.42	1,777	1,948	6.06	6.71	208	266	5.75	171	5
6	42.52	45.98	1,954	2,112	16.42	14.78	372	411	3.46	158	6
7	26.59	31.70	1,593	1,721	.....	.....	.....	.....	5.11	128	7
8	43.36	50.33	2,196	2,369	17.22	18.81	624	648	6.97	173	8
9	34.88	42.24	1,952	2,142	9.19	10.90	400	421	7.36	190	9
10	25.25	31.17	1,532	1,722	.....	.....	.....	.....	5.92	190	10
11	46 77	54.46	2,293	2,589	21.61	23.34	756	859	7.69	296	11
12	46.99	55.10	2,283	2,574	21.93	24.02	739	837	8.11	291	12
13	24.97	31.04	1,549	1,744	.....	.....	.....	.....	6.07	195	13
14	43.43	49.59	2,199	2,303	18.93	19.23	661	568	6.16	104	14
15	32.19	37.92	1,807	1,958	8 16	8.26	279	235	5.73	151	15
16	23.56	28.97	1,517	1,713	.....	.....	.....	.....	5.41	196	16
17	46.77	54.64	2,270	2,505	22.34	24.85	718	773	7.87	235	17
18	55.47	60.83	2,539	2,709	30.17	30 22	952	957	5.36	170	18
19	26.18	31.43	1,622	1,771	.....	.....	.....	.....	5.25	149	19
20	43.24	48.85	2,130	2,338	17.68	17.64	511	568	5.61	208	20
21	46.68	53.98	2,253	2,474	21.73	22.98	638	705	7.30	221	21
22	24.34	30.79	1,612	1,768	.....	.....	.....	.....	6.45	156	22
23	47.42	54.06	2,267	2,496	22.10	22.50	638	703	6.64	229	23
24	45.79	55.35	2,201	2,530	19.51	23.03	555	714	9.56	329	24
25	27.26	33.08	1,663	1,841	.....	.....	.....	.....	5.82	178	25
26	45.47	50.80	2,321	2,419	17.99	17.54	643	585	5.33	98	26
27	47.20	52.02	2,286	2,459	19.50	18.58	593	634	4.82	173	27
28	27.91	33.62	1,708	1,817	.....	.....	.....	.....	5.71	109	28
29	45.58	51.16	2,328	2,504	17.67	17.54	620	687	5.58	176	29
30	48.43	51.42	2,306	2,421	20.51	17.81	598	604	2.99	115	30
*	25.66	31.34	1,591	1,746	.....	.....	.....	.....	5.68	155	
†	42.95	49.20	2,153	2,344	.....	.....	.....	.....	6.25	191	
‡	.....	.....	.....	.....	17.16	17.75	534	593	.....	.....	

*Average unfertilized yields.
†Average fertilized yields.
‡Average increase from fertilizers.

AVERAGE YIELDS BY PERIODS

Period	Treatment	Yield per acre: Unlimed Bu.	Yield per acre: Limed Bu.
I: 1894-1899:	Unfertilized	30.50	.....
	Fertilized	38.27	.....
II: 1900-1913:	Unfertilized	25.96	34.21
	Fertilized	44.02	51.27
III: 1914-1918:	Unfertilized	21.45	28.03
	Fertilized	38.56	45.95

The reduced yields of corn during the last period have apparently been largely due to the partial failure of the clover crop.

TABLE XIV.—Effect on OATS of liming the land. Yield and increase per acre, 1901 and 1905-1918. (15 crops)
(For fertilizer treatment see Table VI.)

Plot No.	Total yield				Increase from fertilizers				Gain for lime		Plot No.
	Grain		Straw		Grain		Straw				
	Unlimed	Limed	Unlimed	Limed	Unlimed	Limed	Unlimed	Limed	Grain	Straw	
	Bu.	*Bu.*	*Lb.*	*Lb.*	*Bu.*	*Bu.*	*Lb.*	*Lb.*	*Bu.*	*Lb.*	
1	32.79	35.88	1,387	1,703	.....	.....	.....	.....	3.09	316	1
2	42.58	46.30	1,836	2,134	11.60	10.89	500	495	3.72	298	2
3	32.63	38.32	1,398	1,789	3.46	3.38	114	215	5.69	391	3
4	27.37	34.48	1,233	1,510	.....	.....	.....	.....	7.11	277	4
5	33.18	38.95	1,444	1,772	5.09	4.53	194	225	5.77	328	5
6	49.32	50.55	2,164	2,386	20.52	16.20	898	801	1.23	222	6
7	29.53	34.29	1,283	1,622	.....	.....	.....	.....	4.76	339	7
8	45.24	50.13	2,060	2,453	15.69	15.69	792	847	4.89	393	8
9	36.95	42.98	1,694	2,164	7.38	8.39	442	576	6.03	470	9
10	29.59	34.74	1,237	1,572	.....	.....	.....	.....	5.15	335	10
11	52.27	53.23	2,637	2,702	22.68	18.17	1,378	1,107	.96	65	11
12	50.91	53.69	2,369	2,716	21.33	18.32	1,088	1,097	2.78	347	12
13	29.58	35.69	1,302	1,642	.....	.....	.....	.....	6.11	340	13
14	41.22	44.31	1,842	1,992	11.60	9.42	547	418	3.09	150	14
15	33.79	38.05	1,452	1,677	4.14	3.96	164	171	4.26	225	15
16	29.69	33.29	1,281	1,439	.....	.....	.....	.....	3.60	158	16
17	54.81	55.63	2,773	2,995	24.78	21.47	1,459	1,496	.82	222	17
18	46.81	48.35	2,257	2,542	16.44	13.34	908	983	1.54	285	18
19	30.72	35.88	1,382	1,619	.....	.....	.....	.....	5.16	237	19
20	40.09	44.03	1,772	2,128	9.94	8.43	451	521	3.94	346	20
21	50.53	54.57	2,465	2,561	20.94	19.25	1,206	966	4.04	96	21
22	29.02	35.04	1,198	1,583	.....	.....	.....	.....	6.02	385	22
23	51.11	53.71	2,496	2,656	21.74	18.24	1,258	1,067	2.60	160	23
24	51.46	54.64	2,514	2,700	21.73	18.75	1,236	1,105	3.18	186	24
25	30.08	36.32	1,318	1,600	.....	.....	.....	.....	6.24	282	25
26	49.63	50.13	2,361	2,435	18.75	13.63	1,017	857	.50	74	26
27	51.99	52.28	2,535	2,674	20.30	15.59	1,165	1,119	.29	139	27
28	32.49	36.87	1,396	1,532	.....	.....	.....	.....	4.38	136	28
29	50.67	50.39	2,567	2,376	18.18	13.52	1,171	844	—.28	—191	29
30	51.32	51.19	2,374	2,456	18.84	14.32	978	924	—.13	82	30
*	30.09	35.25	1,302	1,582	.....	.....	.....	.....	5.16	280	
†	45.83	48.57	2,150	2,365	.....	.....	.....	.....	2.74	215	
‡	.....	.....	.....	.....	15.76	13.27	848	794	.....	.....	

*Average unfertilized yields.
†Average fertilized yields.
‡Average increase from fertilizers.

AVERAGE YIELDS BY PERIODS

Period	Treatment	Yield per acre	
		Unlimed	Limed
		Bu.	Bu.
I: 1894-1904:	Unfertilized	31.10	.....
	Fertilized	43.32	.....
II: 1905-1913:	Unfertilized	27.51	30.23
	Fertilized	42.09	43.63
III: 1914-1918:	Unfertilized	35.24	45.28
	Fertilized	53.31	58.46

The large gain in the yield of oats during the last period is in part at least due to favorable seasonal conditions.

TABLE XV:—Effect on WHEAT of liming the land. Yield and increase per acre, 1906-1918 (For fertilizer treatment see Table VIII.)

Plot No.	Total yield				Increase from fertilizers				Gain for lime		Plot No.
	Grain		Straw		Grain		Straw		Grain	Straw	
	Unlimed	Limed	Unlimed	Limed	Unlimed	Limed	Unlimed	Limed			
	Bu.	*Bu.*	*Lb.*	*Lb.*	*Bu.*	*Bu.*	*Lb.*	*Lb.*	*Bu.*	*Lb.*	
1	13.65	16.03	1,387	1,584	.....	.....	.....	.....	2.38	197	1
2	21.24	24.95	2,005	2,455	8.01	9.18	685	906	3.71	450	2
3	13.46	16.61	1,313	1,736	.66	1.11	60	222	3.15	423	3
4	12.37	15.24	1,186	1,479	.....	.....	.....	.....	2.87	293	4
5	14.62	17.01	1,618	1,795	2.24	1.40	438	282	2.39	177	5
6	28.16	30.54	2,802	3,097	15.77	14.56	1,630	1,548	2.38	295	6
7	12.40	16.35	1,165	1,582	.....	.....	.....	.....	3.95	417	7
8	21.85	26.53	2,153	2,571	9.44	10.32	970	1,018	4.68	418	8
9	15.52	19.17	1,609	1,913	3.11	3.11	409	388	3.65	304	9
10	12.41	15.92	1,218	1,495	.....	.....	.....	.....	3.51	277	10
11	31.07	32.22	3,260	3,432	18.93	16.22	2,064	1,943	1.15	172	11
12	31.19	33.58	3,417	3,584	19.31	17.50	2,243	2,100	2.39	167	12
13	11.61	16 15	1,151	1,478	.....	.....	.....	.....	4.54	327	13
14	28.85	29.94	3,002	3,057	17.32	14.34	1,862	1,601	1.09	55	14
15	27.28	29.79	2,868	2,990	15.83	14.76	1,740	1,556	2.51	122	15
16	11.36	14.48	1,116	1,413	.....	.....	.....	.....	3.12	297	16
17	27.09	30.92	2,813	3,267	15.34	15.84	1,637	1,773	3.83	454	17
18	29.15	32.64	3,114	3,490	17.01	16.94	1,877	1,916	3.49	376	18
19	12.53	16.31	1,297	1,655	.....	.....	.....	.....	3.78	358	19
20	23.36	26.81	2,384	2,660	11.18	10.66	1,128	1,054	3.45	276	20
21	25.38	28.67	2,674	2,957	13.54	12.68	1,459	1,400	3.29	283	21
22	11.51	15.82	1,174	1,508	.....	.....	.....	.....	4.31	334	22
23	23.83	28.89	2,475	2,994	12.07	13.02	1,282	1,443	5.06	519	23
24	24.41	30.63	2,621	3,155	12.39	14.73	1,411	1,560	6.22	534	24
25	12.28	15.94	1,228	1,638	.....	.....	.....	.....	3.66	410	25
26	27.44	27.69	2,870	2,803	15.25	11.93	1,648	1,217	.25	— 67	26
27	27.04	30.01	2,919	3,031	14.96	14.44	1,703	1,497	2.97	112	27
28	11.99	15.40	1,209	1,483	.....	.....	.....	.....	3.41	274	28
29	29.35	28.76	3,268	2,910	17.36	13.36	2,059	1,427	—.59	—358	29
30	26.50	27.28	2,779	2,762	14.51	11.88	1,570	1,279	.78	— 17	30
*	12.21	15.76	1,213	1,531	.....	.....	.....	.....	3.55	318	
†	24.84	27.63	2,598	2,833	.....	.....	.....	.....	2.79	235	
‡	.....	.....	.....	.....	12.71	11.90	1,394	1,306	.....	.....	

*Average unfertilized yields.
†Average fertilized yields.
‡Average increase from fertilizers.

AVERAGE YIELDS BY PERIODS

Period	Treatment	Yield per acre	
		Unlimed	Limed
		Bu.	Bu.
I: 1894-1905:	Unfertilized	8.63	.....
	Fertilized	19.03	.....
II: 1906-1913:	Unfertilized	12.54	15.01
	Fertilized	24.28	26.25
III: 1914-1918:	Unfertilized	11.67	16.96
	Fertilized	25.67	29.84

The wheat passed through two attacks of Hessian fly during the first period, but the last period has been a prosperous one for this crop.

TABLE XVI.—Effect on CLOVER and TIMOTHY of liming the land. Yield and increase per acre: clover, 1903-1918; timothy, 1906-1918
(For fertilizer treatment see Table IX.)

Plot No.	Clover					Timothy					Plot No.
	Total yield		Increase from fertilizers		Gain for lime	Total yield		Increase from fertilizers		Gain for lime	
	Unlimed	Limed	Unlimed	Limed		Unlimed	Limed	Unlimed	Limed		
	Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	
1	1,349	2,023	.....	.....	674	2,493	3,015	.....	.....	522	1
2	1,711	2,556	407	608	845	2,723	3,797	307	768	1,074	2
3	1,364	1,999	105	127	635	2,340	3,241	55	199	901	3
4	1,213	1,796	.....	.....	583	2,263	3,055	.....	.....	792	4
5	1,555	2,316	358	491	761	2,716	3,401	497	337	685	5
6	2,333	3,153	1,151	1,298	820	3,191	4,026	1,016	954	835	6
6	1,166	1,884	.....	.....	718	2,131	3,081	.....	.....	950	7
8	1,997	3,082	860	1,243	1,085	2,755	3,850	657	807	1,095	8
9	1,514	2,204	405	410	690	2,408	3,357	343	352	949	9
10	1,081	1,749	.....	.....	668	2,032	2,967	.....	.....	935	10
11	2,496	3,320	1,388	1,581	824	3,117	4,095	1,060	1,169	978	11
12	2,573	3,428	1,442	1,699	855	3,159	4,123	1,076	1,238	964	12
13	1,156	1,718	.....	.....	562	2,108	2,844	.....	.....	736	13
14	1,999	2,744	873	1,061	745	2,614	3,511	520	641	897	14
15	1,736	2,485	638	837	749	2,492	3,276	411	381	784	15
16	1,068	1,612	.....	.....	544	2,067	2,920	.....	.....	853	16
17	2,372	3,496	1,281	1,813	1,124	2,969	4,596	858	1,569	1,627	17
18	3,374	4,301	2,258	2,545	927	4,190	5,485	2,034	2,351	1,295	18
19	1,139	1,828	.....	.....	689	2,199	3,241	.....	.....	1,042	19
20	2,246	3,011	1,148	1,264	765	3,205	4,433	1,059	1,315	1,228	20
21	2,022	3,068	965	1,401	1,046	2,772	4,039	679	1,045	1,267	21
22	1,015	1,586	.....	.....	571	2,039	2,872	.....	.....	833	22
23	1,923	3,140	844	1,481	1,217	2,730	4,057	597	1,051	1,327	23
24	1,986	3,374	842	1,643	1,388	2,740	4,365	512	1,224	1,625	24
25	1,208	1,803	.....	.....	595	2,323	3,275	.....	.....	952	25
26	2,719	3,544	1,486	1,737	825	3,070	4,554	716	1,295	1,484	26
27	2,267	3,139	1,009	1,326	872	2,864	4,257	481	1,014	1,393	27
28	1,283	1,817	.....	.....	534	2,414	3,227	.....	.....	813	28
29	2,823	3,221	1,540	1,404	398	3,384	4,107	970	880	723	29
30	2,718	3,397	1,435	1,580	679	3,491	4,381	1,076	1,154	890	30
*	1,168	1,781	.....	.....	613	2,207	3,050	.....	.....	843	
†	2,186	3,049	.....	.....	863	2,946	4,047	.....	.....	1,101	
‡	.....	.....	1,022	1,277	.....	.....	.....	746	987	....	

*Average unfertilized yields.
†Average fertilized yields.
‡Average increase from fertilizers.

AVERAGE YIELDS BY PERIODS

Period	Treatment	Yield per acre: Clover, Unlimed	Clover, Limed	Timothy, Unlimed	Timothy, Limed
		Lb.	Lb.	Lb.	Lb.
I:	Unfertilized	1,712	.....	2,443	.....
	Fertilized	2,402	.....	3,007	.....
II:	Unfertilized	1,409	1,982	2,198	2,822
	Fertilized	2,461	3,391	2,858	3,774
III:	Unfertilized	638	1,338	1,339	2,194
	Fertilized	1,581	2,297	1,909	2,865

The large reduction in the yields of clover and timothy during the last period appear to have been chiefly due to a diseased condition affecting the clover, for which lime is not a sufficient corrective. The failure of the clover has been followed by reduced yields of both timothy and corn.

TABLE XVII.—Total effect on the 5 crops of the rotation of liming the land. Total fertilizing materials and their cost; total and net value of increase from fertilizers and of increase from lime per rotation

Plot No.	Fertilizing material in pounds per acre for each rotation	Cost of fertilizers for each rotation	Average value of increase from fertilizers per rotation		Net gain from fertilizers per rotation		Average increase from lime per rotation	Plot No.
			Unlimed	Limed	Unlimed	Limed		
		Dollars	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	
1	None						10.72	1
2	Acid phosphate, 320	2.60	17.72	21.31	15.12	18.71	14.96	2
3	Muriate of potash, 260	6.50	5.31	7.36	—1.19	.86	14.34	3
4	None						12.74	4
5	Nitrate of soda, 440; dried blood, 50	14.40	10.11	9.38	—4.29	—5.02	12.49	5
6	Acid phosphate, 320; nitrate of soda, 440; dried blood, 50	17.00	37.09	34.39	20.09	17.39	11.03	6
7	None						14.25	7
8	Acid phosphate, 320; muriate of potash, 260	9.10	27.91	31.52	18.81	22.42	17.79	8
9	Muriate of potash, 260; nitrate of soda, 440; dried blood, 50	20.90	12.82	14.01	—8.08	—6.89	15.31	9
10	None						14.03	10
11	Acid phosphate, 320; muriate of potash, 260; nitrate of soda, 440; dried blood, 50	23.50	44.96	43.10	21.46	19.60	12 17	11
12	Acid phosphate, 320; muriate of potash, 260; nitrate of soda, 680; dried blood, 50	30.70	45.13	45.30	14.43	14.60	14.22	12
13	None						14.04	13
14	Acid phosphate, 240; muriate of potash, 180; nitrate of soda, 280; dried blood, 50	16.05	33.88	31.67	17.83	15.62	11.19	14
15	Acid phosphate, 160; muriate of potash, 100; nitrate of soda, 120; dried blood, 50	8.60	23.69	23.25	15.09	14.65	12.29	15
16	None						12.08	16
17	Acid phosphate, 480; muriate of potash, 200; nitrate of soda, 220; dried blood, 25	17.60	41.37	47.01	23.77	29.41	18.49	17
18	Yard manure, 16 tons	?	51.99	53.55	?	?	15.21	18
19	None						14.41	19
20	Yard manure, 8 tons	?	30.17	30.86	?	?	15.09	20
21	Same elements as 17, but nitrogen in oilmeal	17.60	36.00	38.32	18.40	20.72	16.73	21
22	None						14.40	22
23	Same elements as 17, but nitrogen in dried blood	17.60	34.18	38.58	16.58	20 98	17.08	23
24	Same elements as 17, but nitrogen in sulphate ammonia	17.60	33.13	41.83	15.53	24.23	23.02	24
25	None						14.28	25
26	Same elements as 11, but phosphorus in bonemeal	23.50	37.46	35.73	13.96	12.23	11.86	26
27	Same elements as 17, but nitrogen in nitrate of lime	17.60	35.57	36.59	17.97	18.99	13.96	27
28	None						12.25	28
29	Same elements as 11, but phosphorus in basic slag	23.50	40.61	34.20	17.11	10.70	5.88	29
30	Same elements as 17, but nitrogen in tankage	17.60	38.95	34.99	21.35	17.39	8.29	30

AVERAGE TOTAL VALUE OF THE 5 CROPS OF THE ROTATION BY PERIODS

Period	Treatment	Values for 1 acre for 5 years: Unlimed	Limed	Gain for lime
I:	Unfertilized	$49.41	$.....	$.....
	Fertilized	71.20	.....	.....
	Gain for fertilizing	21.79	.....	.....
II:	Unfertilized	$48.07	$59.77	$11.70
	Fertilized	79.00	91.93	12.93
	Gain for fertilizing	30.93	31.16	.....
III:	Unfertilized	$41.90	$58.22	$16.32
	Fertilized	73.59	89.27	15.68
	Gain for fertilizing	31.69	31.05	.....

The outcome shows a remarkably uniform return from the fertilizing throughout both the last two periods; that is, since the completion of the first rotation has brought out the full effect of the fertilizers, and also shows that the diminishing yields of the hay and corn crops during the last period have been largely offset by an increasing effect from the liming.

IV: THE LIME AND FLOATS TEST

This experiment was begun at Wooster in 1905 in a 3-year rotation of corn, oats and clover, for the purpose of comparing the effect of different forms of lime and of obtaining further experience in the use of untreated phosphate rock.

The land had been under the regular rotative cropping of the farm since its occupation by the Station, and for a considerable period before, and was in good condition. Twelve tons of manure per acre had been plowed under for corn in 1904. Three sections of 26 plots each are included in the test, the plots containing one-twentieth acre each.

For the crops of 1905 Section A (north end) was manured at the rate of 6 tons per acre only, because of the recent application above mentioned, and then was limed and fertilized and planted in corn. Section B was sown to soybeans instead of clover, the beans being followed by rye in the fall and corn in 1906. Section C (south end) was limed and fertilized without manure, and sown to oats and clover. Thenceforth the manure, lime and fertilizers have all been applied to the corn crops, the manure being plowed under and the lime and fertilizers applied on the surface. The oats and clover receive no treatment.

The clover seeding failed in 1906, 1908 and 1909, and soybeans were grown instead and harvested as hay. As the soybean suffers less from lack of lime than clover the result has been a smaller apparent effect from the lime than might otherwise have been found.

The plan of treatment and average results of the work for the first fourteen years are given in Table XVIII.

The detail records of this experiment show that the cessation of the systematic manuring of the land that had previously been practiced was followed by a rapid decrease in yield, the yields on the unmanured and unfertilized check plots falling from 57.70 bushels of corn, 51.90 bushels of oats and 4,673 pounds of hay for the first 6 years of the experiment to 38.43 bushels of corn, 33.60 bushels of oats and 2,245 pounds of hay for the next 6 years—a decline of one-third in the yields of corn and oats and of one-half in that of hay.

Considering the eight plots that have received both manure and lime since the beginning of the experiment, there has been a decline of 6 percent in the yield of corn, 14 percent in that of oats, and 27 percent in that of hay, this reduction in the clover yield being apparently due, in part at least, to a clover disease that has materially reduced the yield of that crop during recent years. This reduction in clover yield would account for the falling off in that of corn.

As between acid phosphate and floats, the effect of 320 pounds of floats has been 62 percent of that of the same weight of 14 percent acid phosphate when used alone, 60 percent when used with muriate of potash, and 75 percent when used with muriate of potash and lime.

The use of 1,000 pounds of floats as a supplement to 8 tons of manure, the floats being applied to the surface after turning under the manure, has not equalled in effectiveness the mixture of one-third this quantity of floats with the same quantity of manure in the experiment described further on. (See page 613.)

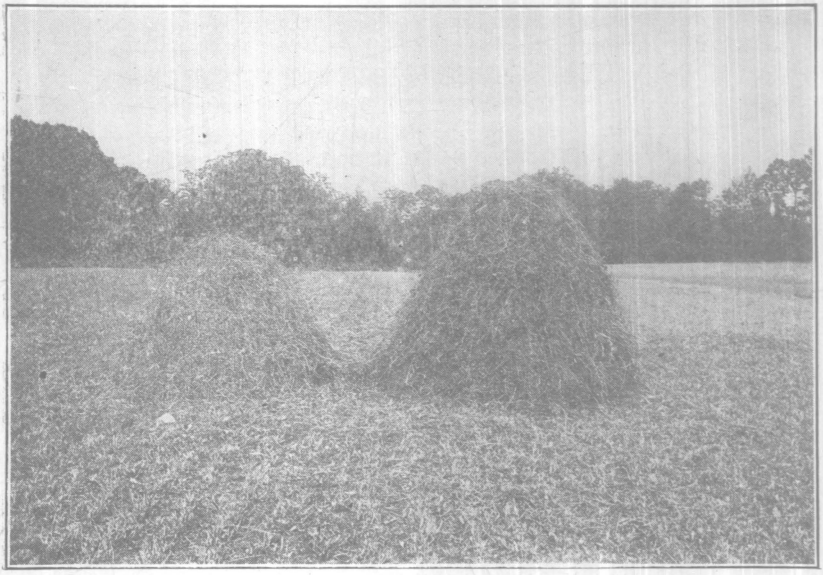
TABLE XVIII.—Crops grown in 3-year rotation at Wooster under treatment with manure, lime and floats

Plot No.	Treatment (Lime, manure, etc., per acre applied to corn only)	Corn—14 years				Oats—14 years				Clover—13 years		Total value of increase	Plot No.
		Grain		Stover		Grain		Straw		Yield	Increase		
		Yield	Increase	Yield	Increase	Yield	Increase	Yield	Increase				
		Bu.	*Bu.*	*Lb.*	*Lb.*	*Bu.*	*Bu.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Dollars*	
1	None	46.27	.....	2,474	.....	47.08	.....	2,063	.....	3,633	.....	.....	1
2	Caustic lime, 500 lb.; manure, 8 tons	66.07	19.60	3,209	721	56.85	8.89	2,394	381	4,802	1,129	16.48	2
3	Caustic lime, 1,000 lb.; manure, 8 tons	67.55	20.88	3,254	750	56.82	7.98	2,347	383	4,907	1,192	17.02	3
4	None	46.86	.....	2,518	.....	49.71	.....	1,914	.....	3,755	.....	.....	4
5	Caustic lime, 2,000 lb.; manure, 8 tons	71.78	24.14	3,514	969	58.06	8.42	2,460	544	5,260	1,516	20.24	5
6	Ground limestone, 1,780 lb.; manure, 8 tons	70.34	21.91	3,336	764	57.59	8.02	2,331	414	4,916	1,184	17.47	6
7	None	49.20	.....	2,599	.....	49.50	.....	1,918	.....	3,720	.....	.....	7
8	Air slaked lime, 1,780 lb.; manure, 8 tons	71.21	22.78	3,491	929	59.24	10.78	2,450	580	5,130	1,526	20.42	8
9	Hydrated lime, 1,320 lb.; manure 8 tons	68.56	20.91	3,378	855	58.74	11.31	2,405	583	4,909	1,420	19.30	9
10	None	46.88	.....	2,485	.....	46.40	.....	1,775	.....	3,373	.....	.....	10
11	Gypsum, 1,000 lb.; manure, 8 tons	61.46	15.65	3,062	624	56.01	9.67	2,177	437	4,012	704	13.35	11
12	Floats, 1,000 lb.; manure, 8 tons	63.06	18.32	3,065	674	58.39	12.12	2,251	548	4,329	1,087	16.87	12
13	None	43.66	.....	2,344	.....	46.20	.....	1,668	.....	3,176	.....	.....	13
14	Caustic lime, 1,000 lb.	53.00	9.71	2,811	459	51.28	5.05	1,898	244	4,066	912	9.98	14
15	Ground limestone, 1,780 lb.	49.11	6.20	2,534	174	49.27	3.01	1,798	158	3,801	668	6.47	15
16	None	42.52	.....	2,368	.....	46.28	.....	1,626	.....	3,112	.....	.....	16
17	Caustic lime, 1,000 lb.; acid phos., 320 lb.; muriate potash, 40 lb.	65.28	22.10	3,201	829	56.57	10.12	2,066	395	4,510	1,364	18.97	17
18	Caustic lime, 1,000 lb.; floats, 320 lb.; muriate potash, 40 lb.	60.19	16.36	3,046	670	53.16	6.54	1,910	194	4,327	1,147	14.29	18
19	None	44.48	.....	2,381	.....	46.79	.....	1,761	.....	3,215	.....	.....	19
20	Acid phosphate, 320 lb	53.70	9.56	2,671	321	50.20	4.00	1,788	65	3,474	269	6.65	20
21	Acid phos., 320 lb.; mur. of potash, 40 lb	58.78	15.00	2,912	593	51.07	5.45	1,903	218	3,619	423	10.43	21
22	None	43.44	.....	2,288	.....	45.04	.....	1,647	.....	3,186	.....	.....	22
23	Floats, 320 lb	48.17	5.77	2,445	183	46.92	2.85	1,713	97	3,239	152	4.14	23
24	Floats, 320 lb.; muriate potash, 40 lb	51.21	9.86	2,679	445	46.34	3.24	1,658	73	3,133	146	6.24	24
25	None	40.29	.....	2,209	.....	42.14	.....	1,555	.....	2,888	.....	.....	25
26	Manure, 8 tons since 1909*	53.46		2,792		43.19		1,402		3,249			26
	Average unfertilized yield	44.86	.....	2,407	.....	46.57	....	1,769	.....	3,340	.....	.....	

*Previously, floats, 320 lbs.; muriate of potash, 40 lbs.; dried blood, 100 lbs. **Increase since 1909.**

Notice: The lime or gypsum or floats and manure are not mixed together. The manure is plowed under and the lime or other materials applied to the surface.

Stall manure 8 tons and acid phosphate 320 pounds per acre, all on the corn crop preceding the wheat. Twenty-one year average yield per acre, 64.2 bu. corn, 28.2 bu. wheat, 2 1-6 tons hay



Yields of clover on unlimed and limed land receiving no fertilizer

V: SUPPLEMENTAL LIMING TESTS AT WOOSTER

In 1915 an experiment was begun in the use of lime in a 4-year rotation of corn, oats, wheat and clover, each crop being grown every year, the object being to compare the effect of different quantities and different fineness of grinding of limestone; of raw limestone with burnt (hydrated) lime; and of application to different crops in the rotation. The plan of this experiment and the results for the average of the first 4 years are given in Table XIX.

The first applications have not strictly followed the plan as given in the table, some variation having been made in order to get on the full quantity of lime or limestone during the first rotation. The table, therefore, is useful in showing the comparative immediate effect of finely ground and coarsely ground limestone and hydrated lime, but it will require another rotation at least before much light can be thrown on the other questions proposed.

The "fine" limestone used in this test is the product of the State Penitentiary at Columbus, a stone analyzing about 85 percent calcium carbonate and 5 percent magnesium carbonate, 35 to 45 percent of which passes through a sieve having 100 meshes to the linear inch and all through one having 10 meshes to the inch. This has also been used for the "non magnesian" limestone on Plot 17.

The coarse limestone is the grade known as screenings, all of which passes through a quarter-inch sieve.

The "magnesian" stone is a dolomite from western Ohio, analyzing about 54 percent calcium carbonate and 43 percent magnesium carbonate.

The non-magnesian burnt lime has contained about 66 percent calcium oxide and 1.4 percent magnesium oxide, and the magnesian hydrated lime about 45 percent calcium oxide and 32 percent magnesium oxide.

The lime carriers are analyzed each year and are applied to the land in such quantities as to give the same total neutralizing material to each plot, so that the magnesian lime or limestone is used in smaller relative quantity than the non-magnesian.

The entire land, both limed and unlimed, receives a basic dressing of 8 tons per acre of farm manure on corn and 320 pounds of acid phosphate on wheat.

It is too soon as yet to ascribe more than a tentative value to the figures given in the table, but if we compute coarse limestone laid on the land at $3.75 a ton, fine limestone at $6, and hydrated lime at $11, the outcome at this stage of the work would be as shown below:

Plot	Treatment	Total value of increase	Cost of liming	Net value of increase
9	Coarse limestone, 2 tons per acre	$15.78	$ 7.50	$ 8.28
11	Coarse limestone, 4 tons per acre	23.60	15.00	8.60
2-4-17	Fine limestone, 2 tons per acre	24.16	12.00	12.16
12	Fine limestone, 4 tons per acre	33.38	24.00	9.38
15-18	Hydrated lime, 1½ tons per acre	28.52	16.50	12.02

TABLE XIX.--Liming the land: Place in rotation, quantity and fineness of grinding: Limestone vs. Hydrated Lime. Wooster Experiments.

PART I.—Average yield and increase per acre, 1915-1918.*

Average Yield per Acre.

Plot	Kind and Condition of Limestone or Lime, Treatment per acre†	Corn		Oats		Wheat		Clovr
		Grain	Stovr	Grain	Str'w	Grain	Str'w	Hay
		Bu.	Lb.	Bu.	Lb.	Bu.	Lb.	Lb.
1	None	50.58	2,412	62.77	2,516	27.72	2,851	3,735
2	Limestone, fine, 2 tons on corn	57.12	2,688	64.45	2,427	28.80	2,727	5,004
3	Limestone, fine, 2 tons on wheat	53.41	2,504	63.12	2,475	29.41	2,740	4,859
4	None	48.16	2,282	61.60	2,004	27.13	2,557	3,194
5	Limestone, fine, 2 tons on clover, new seeding in fall	51.87	2,517	62.22	2,211	28.38	2,667	3,884
6	Limestone, fine, 2 tons on clover sod, before plowing	53.20	2,477	61.87	2,275	29.54	2,567	3,887
7	None	43.25	2,154	60.23	2,310	25.58	2,340	2,786
8	Limestone, fine, ½ ton on each crop	48.23	2,387	60.87	2,064	26.31	2,166	3,708
9	Limestone, coarse, 2 tons on corn	49.39	2,270	61.36	2,361	26.97	2,266	3,365
10	None	45.11	2,098	62.27	2,392	24.65	2,235	2,649
11	Limestone, coarse, 4 tons on corn	50.75	2,407	62.07	2,366	28.02	2,474	3,537
12	Limestone, fine, 4 tons on corn	54.32	2,467	63.83	2,500	28.28	2,348	3,853
13	None	44.51	2,147	56.87	2,415	24.87	2,195	2,566
14	Limestone, magnesian, fine, 2 tons on corn	52.41	2,458	59.64	2,246	27.28	2,288	3,768
15	Limestone, magnesian, hydrated, 1½ tons on corn	54.50	2,537	62.22	2,496	28.68	2,469	4,060
16	None	45.50	2,191	61.68	2,124	27.01	2,379	3,012
17	Limestone, non-magnesian, fine, 2 tons on corn	50.37	2,285	63.87	2,654	29.57	2,670	3,836
18	Limestone, non-magnesian, hydrated, 1½ tons on corn	53.64	2,449	64.45	2,737	29.48	2,511	3,824
19	None	43.35	2,103	60.15	2,587	25.85	2,319	3,013
20	Limestone, fine, 8 tons on corn	56.95	2,507	63.83	2,947	29.64	2,521	4,390
	Average unlimed yield	45.78	2,198	60.80	2,335	26.12	2,382	2 994

PART II.—Increase from liming.

Plot	Kind and Condition of Limestone or Lime. Treatment Per Acre	Corn		Oats		Wheat		Hay	Total Value of Increase ‡
		Grain	Stover	Grain	Straw	Grain	Straw		
		Bu.	Lb.	Bu.	Lb.	Bu.	Lb.	Lb.	
2	Fine, 2 tons on corn	7.35	319	2.07	82	1.28	107	1,450	$26.67
3	Fine, 2 tons on wheat	4.44	179	1.13	300	2.08	152	1,484	25.38
5	Fine, 2 tons on clover, new seeding	5.34	278	1.08	106	1.62	259	826	18.97
6	Fine, 2 tons on clover sod	8.31	280	1.18	67	3.45	154	965	26.57
8	Fine, ½ ton on each crop	4.36	252	-0.04	— 273	1.04	— 139	968	15.79
9	Coarse, 2 tons on corn	4.90	154	-0.22	— 4	2.01	— 4	670	15.78
11	Coarse, 4 tons on corn	5.84	292	1.60	— 34	3.29	252	916	23.60
12	Fine, 4 tons on corn	9.61	336	5.15	92	3.48	139	1,259	33.38
14	Fine, 2 tons on corn (magnesian)	7.57	296	1.17	— 72	1.70	32	1,053	22.86
15	Hydrated, 1½ tons on corn "	9.43	361	2.14	275	2.37	152	1,196	28.99
17	Fine, 2 tons on corn (non-magnesian)	5.59	123	2.69	375	2.94	311	824	22.94
18	Hydrated, 1½ tons on corn "	9.57	316	3.79	305	3.25	172	811	28.04
20	Fine, 8 tons on corn	13.59	404	3.67	360	3.79	202	1,376	39.07

*Corn, oats and wheat, each 4 crops; clover, 3 crops.

†All plots receive 8 tons of manure per acre on corn and 320 pounds of acid phosphate on wheat.

‡Computing corn at $1 per bushel; oats at 60 cents; wheat at $2; stover and straw at $4 per ton and hay at $20 per ton.

VI: LIMING EXPERIMENTS ON THE STRONGSVILLE FARM

In 1906 an experiment was begun in the use of limestone on land that had lain in pasture for 30 years or longer. It was not practicable to drain the land at the beginning of the experiment, except by the surface drains produced by ridging the plots, but in 1914 it was tile drained with drains running across the plots. It was arranged in 3 sections of 30 tenth-acre plots each and a 3-year rotation of corn, wheat and clover was started on the plan shown in Table XX, each crop being grown every year after the rotation was established. Because of the difficulty in getting the corn off the land in time for wheat—a difficulty much greater here than farther south, not only because of the difference in latitude, but also because of the cold nature of this soil—the rotation was changed in 1915 to one of corn, oats and clover.

In Table XX the average yields of corn are given for 12 years, those of wheat for 5 years, those of oats for 4 years and those of hay for 9 years, the wheat having failed entirely in 1907, 1909 and 1913, and the clover in 1910 and 1913. No corn was grown in 1908 and the treatment was suspended for that year.

Table XXI shows the entire quantity of fertilizing materials and limestone applied during the 13 years of the experiment, and the value of the total produce and of the increase due to the liming, using the low valuations heretofore employed.*

The increase produced by liming has been computed on the assumption that the variations in natural fertility have been progressive from plot to plot. The abnormally low yields on Plots 1 and 30 cause this method of computation to give a relatively high value to the increase on Blocks I and VI, but do not materially affect the general outcome, which is that the larger applications of limestone, made at longer intervals, seem to have produced a greater effect than the smaller quantities more frequently applied, except that after the quantity has reached 2 tons for each 3-year period there has been no further increase.

This outcome supports the view that the first liming should be large enough to fully neutralize the land, and that it may be a better practice, as well as a more economical one, to make larger and less frequent applications. It does not cost twice as much to spread 2 tons to the acre as 1 ton, although of course other expenses are proportionate to the quantity.

Nitrate of soda has apparently diminished the requirement for lime, a result in harmony with those attained at Wooster, and indicating that one of the effects of liming is to increase the supply of available nitrogen, but the high cost of the nitrate has reduced the net gain.

The addition of muriate of potash has not produced any additional yield, and its cost has therefore reduced the net gain. This result is in harmony with other experiments on this farm (see page 622) in which the addition of potash to the fertilizer has failed to produce sufficient increase to cover its cost.

The reinforcement of manure with phosphorus, by which the nitrogen of the manure is more fully utilized, has apparently diminished the lime requirement, while in the absence of the phosphate lime seems to have partially taken its place.

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*Corn, 40 cents; wheat, 80 cents; oats, 30 cents a bushel. Stover, $3; straw, $2, and hay $8 a ton.

TABLE XX.—Liming Experiment at Strongsville.

Average Annual Yield per Acre.

Plot No.	Basic Treatment (Oats instead of wheat 1915 and since.)	Liming (All on corn.)	Corn		Wheat		Oats		Clovr
			Grain	Stover	Grain	Straw	Grain	Straw	Hay
			Bu.	Lb.	Bu.	Lb.	Bu.	Lb.	Lb.
Block I 1		None	27.42	1,807	11.19	1,508	44.76	1,455	1,877
2	Acid Phosphate 160 lbs.	1 ton every 3d yr..	36.90	2,199	15.76	1,660	67.19	2,212	2,755
3	On corn and wheat....	2 tons every 6th yr	38.67	2.243	17.97	2,154	65.16	2,172	3,188
4		3 tons every 9th yr	40.52	2,258	17.16	2,174	67 85	2,259	3,243
5		None	30.44	1,877	15.03	1,848	59.92	2,070	2,402
Block II 6		None	31.68	1,931	14.69	1,785	68.75	2,342	2,387
7	Acid phosphate 160 lbs.	1 ton every 3d yr.	38.97	2,192	14.77	1,973	73.08	2,561	2,840
8	Nitrate of soda 80 lbs..	2 tons every 6th yr	39.62	2,247	16.43	2,130	70.53	2,581	3,177
9	On corn and wheat....	3 tons every 9th yr	42.56	2,335	17.83	2,195	76.52	2,686	3,212
10		None	33.86	2,100	16.03	1,852	71.45	2,351	2,619
Block III 11		None	30.60	2,054	14.68	1,807	68.95	2,456	2,455
12	Acid phosphate 160 lbs	1 ton every 3d yr.	37.45	2,331	14.86	1,918	73.71	2,541	2,859
13	Nitrate of soda 80 lbs..	2 tons every 6th yr	38.63	2,310	15.59	2,066	74.72	2,460	3,163
14	Muriate potash 80 lbs.	3 tons every 9th yr	39.36	2,395	16.60	2,132	71.45	2,501	3,179
15	On corn and wheat....	None	30.74	2,092	16.71	1,769	68.47	2,259	2,485
Block IV 16		None	30.23	2,077	16.06	1,732	70.94	2,335	2,376
17	Acid phosphate 160 lbs	2 tons every 3d yr.	44.11	2,468	18.99	2,364	78.51	2,662	3,302
18	Nitrate of soda 80 lbs..	4 tons every 6th yr	43.72	2,559	18.40	2,422	76.09	2,802	3,599
19	Muriate of potash 80 lbs	6 tons every 9th yr	41.24	2,362	19.35	2,413	72.73	2,597	3,571
20	On corn and wheat....	None	33.17	2,237	16.88	1,990	70.58	2,491	2,557
Block V 21	Acid phosphate 160 lbs	None	42.15	2,551	17.15	1,918	64.45	2,212	2,836
22	On corn and wheat....	1 ton every 3d yr.	48.30	2,771	15.96	2,100	70.11	2,544	3,389
23	Manure 8 tons.....	3 tons every 6th yr	48.47	2,890	17.79	2,273	70.86	2,557	3,846
24	On corn only.....	6 tons every 9th yr	48.04	2,828	18.77	2,242	68.98	2,505	4,034
25		None	46.03	2,714	15.57	1,995	63.20	2,190	3,279
Block VI 26		None	37.50	2,440	9.11	1,213	54.25	1,876	2,273
27	Manure 8 tons.....	1 ton evrry 3d yr.	41.81	2,581	9.34	1,441	60.39	1,980	2,559
28	On corn only.....	3 tons every 6th yr	43.91	2,632	11.19	1,619	66.01	2,117	3,325
29		6 tons every 9th yr	44.17	2,695	12.50	1,799	61.44	2,196	3,481
30		None	31.01	2,174	5.97	880	49.65	1,724	2,035

Average Increase per Acre for Liming.

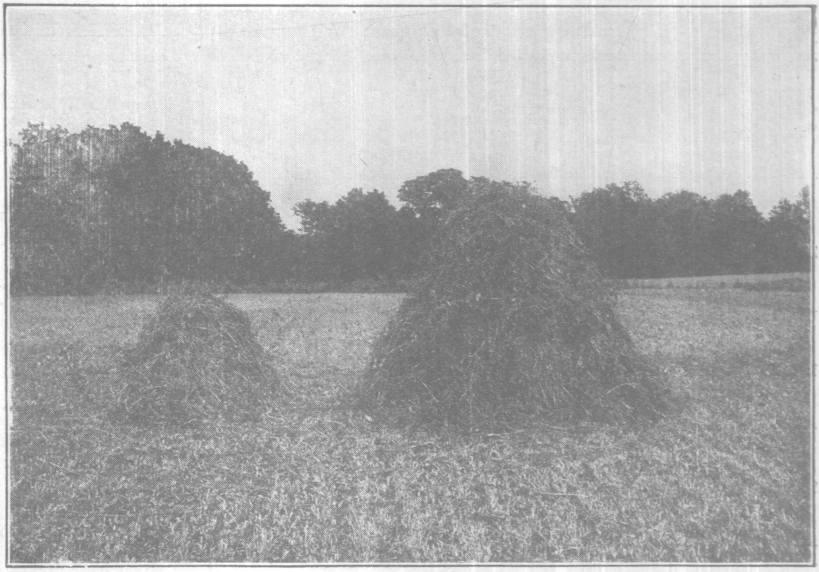
Block I 2		1 ton every 3d yr	8.72	376	3.61	67	18.64	604	746
3	Acid phosphate.....	2 tons every 6th yr	9.74	400	4.86	476	12.82	410	1,049
4		3 tons every 9th yr	10.83	398	3.08	411	11.72	342	973
B. II 7	Acid phosphate.....	1 ton every 3d yr	6.75	219	—0.25	171	3.66	216	395
8	Nitrate of soda.....	2 tons every 6th yr	6.85	232	1.07	312	0.44	234	674
9		3 tons every 9th yr	9.24	278	2.14	361	5.75	327	651
B. III 12	Acid phosphate.....	1 ton every 3d yr	6.81	267	—0.31	340	4.88	134	397
13	Nitrate of soda.....	2 tons every 6th yr	7.96	237	—0.10	323	6.00	102	693
14	Muriate of potash.....	3 tons every 9th yr	8.65	313	0.40	375	2.85	193	702
B. IV 17	Acid phosphate.....	2 tons every 3d yr	13.15	351	2.73	567	7.66	289	880
18	Nitrate of soda.....	4 tons every 6th yr	12.02	402	1.93	560	5.33	389	1,133
19	Muriate of potash.....	6 tons every 9th yr	8.81	165	2.67	487	2.06	145	1,059
B. V 22	Acid phosphate.....	1 ton every 3d yr	5.18	180	—0.80	162	5.97	337	443
23	Manure.....	3 tons every 6th yr	4.38	257	1.43	317	7.03	356	789
24		6 tons every 9th yr	2.98	155	2.81	269	5.47	309	865
B. VI 27		1 ton every 3d yr	5.93	207	1.03	311	7.29	142	346
28	Manure	3 tons every 6th yr	9.66	325	3 64	572	14.06	318	1,172
29		6 tons every 9th yr	11.53	455	5.74	835	10.64	435	1,386

TABLE XXI.—Liming Strongsville land: Total fertilizers, lime and manure applied; total value of crops harvested and value of increase for liming for entire period of 13 years: All per acre

Block No.	Plot No.	Basic treatment	Limestone	Value of total produce	Value of increase for liming
			Tons	*Dollars*	*Dollars*
I	1		.....	342.06	.....
	2		12	475.02	114.95
	3	Acid phosphate, 3,840 lb.	12	508.14	130.06
	4		12	519.69	123.59
	5		.....	414.11	.....
II	6		.....	430.53	.....
	7	Acid phosphate, 3,840 lb.	12	493.72	55.50
	8		12	514.23	68.32
	9	Nitrate of soda, 1,920 lb.	12	544.59	90.98
	10		.....	451.30	.....
III	11		.....	430.39	.....
	12	Acid phosphate, 3,840 lb.	12	490.37	57.62
	13	Nitrate of soda, 1,920 lb	12	511.02	75.91
	14	Muriate of potash, 1,920 lb.	12	517.19	79.73
	15		.....	439.82	.....
IV	16		.....	433.67	.....
	17	Acid phosphate. 3,840 lb.	24	565.21	124.54
	18	Nitrate of soda, 1,920 lb	24	571.69	124.02
	19	Muriate of potash, 1.920 lb.	24	553.76	99.10
	20		.....	461.66	.....
V	21		.....	512.79	.....
	22	Acid phosphate, 3,840 lb.	12	570.27	50.00
	23		18	598.68	70.93
	24	Yard manure, 96 tons	24	603.57	68.34
	25		.....	542.71	.....
VI	26		.....	419.64	.....
	27		12	462.78	59.27
	28	Yard manure, 96 tons	18	516.78	129.40
	29		24	525.52	154.27
	30		.....	355.12	.....

APPROXIMATE EFFECT OF MANURE AND FERTILIZERS

Product of land receiving manure only (Plots 26 and 30)	$387.38
Product for manure and acid phosphate (Plots 21 and 25)	527.75
Increase for acid phosphate	$140.37
Product of land receiving acid phosphate only (Plots 1 and 5)	$378.08
Estimated increase due to acid phosphate	140.37
Approximate unaided yield of land	$237.71
Product of land receiving manure only (Plots 26 and 30)	$387.38
Estimated unaided yield of land	237.71
Approximate increase for manure	$149.67
Product of land receiving acid phosphate only (Plots 1 and 5)	$378.08
Product of land receiving acid phosphate and nitrate of soda (Plots 6 and 10)	445.91
Approximate increase for nitrate of soda	$ 67.83



Yields of clover on unlimed and limed land receiving complete fertilizer, with nitrogen in sulphate of ammonia

Yields of clover on unlimed and limed land receiving barnyard manure

VII: THE BARNYARD MANURE TEST

COMPARISON OF YARD WITH FRESH MANURE. THE REINFORCEMENT OF MANURE

This experiment was begun in 1897 for the purpose of comparing manure which has lain for some months in an open barnyard with that taken directly from the stable to the field, and of studying the effect of treating the manure with several absorbent or reinforcing materials. In the earlier years of this investigation a lot of manure was taken from the open barnyard, where it had been accumulating during the winter, and divided into four parcels. With one parcel was mixed the finely ground phosphatic rock, known as floats, from which acid phosphate is made by mixing it with sulphuric acid; with another parcel acid phosphate was mixed; with a third, the crude potash salt, known as kainit, and with a fourth, land plaster or gypsum; the reinforcing materials being used at the uniform rate of 40 pounds per ton of manure. At the same time manure taken from box stalls, where it had accumulated under the feet of animals kept continuously in their stalls, was divided into similar parcels and treated with like quantities of the same materials.

After a few weeks the manure thus treated, together with two lots of untreated manure, one taken from the yard and one from the stable, was spread upon clover sod at the rate of eight tons per acre and plowed under for corn, the corn being followed by wheat and clover in a 3-year rotation. During the first three seasons soybeans were grown, because of clover failure, and were plowed under.

Because of the uncertainty as to the quantity of fresh manure required to produce a ton of yard manure under these conditions the plan was changed in 1903, and since then a sufficient quantity of fresh manure for the purpose of the experiment is weighed out of the stables in December or January and forked over carefully to secure a uniform product. The manure is then divided into five equal parcels, four of which are treated as above indicated, and the fifth is left untreated. Each parcel is then divided into two equal portions, one of which is immediately spread upon the plots receiving "stall manure," while the other is placed in a flat, compact pile in an open yard, where it remains undisturbed until April, when it is spread on the "yard manure" plots, and the whole is plowed under at the rate of 8 tons of the original manure per acre.

Three tracts of land, A, B and C, are included in the test, each crop being grown every season. The arrangement of these tracts and the plan of fertilizing are shown in Diagram III, and the results are given in Tables XXII to XXIV.

DIAGRAM III.—ARRANGEMENT OF PLOTS AND PLAN OF FERTILIZING IN EXPERIMENTS WITH MANURE

PLOTS ONE-SIXTEENTH ACRE

11	Nothing			Nothing	
12	Yard manure and gypsum			Yard manure and floats	2
13	Stall manure and gypsum			Stall manure and floats	3
14	Nothing			Nothing	4
15	Yard manure, untreated			Yard manure and acid phos.	5
16	Stall manure, untreated			Stall manure and acid phos.	6
17	Nothing			Nothing	7
18	Chemical fertilizer			Yard manure and kainit	8
19	Chemical fertilizer			Stall manure and kainit	9
20	Nothing	SECTION A		Nothing	
11	Nothing			Nothing	1
12	Yard manure and gypsum			Yard manure and floats	2
13	Stall manure and gypsum			Stall manure and floats	3
14	Nothing			Nothing	4
15	Yard manure, untreated			Yard manure and acid phos.	5
16	Stall manure, untreated			Stall manure and acid phos.	6
17	Nothing			Nothing	7
18	Chemical fertilizer			Yard manure and kainit	8
19	Chemical fertilizer			Stall manure and kainit	9
20	Nothing	SECTION B		Nothing	10
11	Nothing			Nothing	1
12	Yard manure and gypsum			Yard manure and floats	2
13	Stall manure and gypsum			Stall manure and floats	3
14	Nothing			Nothing	4
15	Yard manure, untreated			Yard manure and acid phos.	5
16	Stall manure, untreated			Stall manure and acid phos.	6
17	Nothing			Nothing	7
18	Chemical fertilizer			Yard manure and kainit	8
19	Chemical fertilizer			Stall manure and kainit	9
20	Nothing	SECTION C		Nothing	10

NORTH

TABLE XXII.—Barnyard MANURE and chemical fertilizers on corn, followed by wheat and clover in rotation, 1897-1918.
21-year average yield and increase per acre

Plot	Treatment	Yield Per Acre					Increase Per Acre					Plot
		Corn—21 Crops		Wheat—21 Crps		Hay 18 Crops	Corn		Wheat		Hay	
		Grain	Stover	Grain	Straw		Grain	Stover	Grain	Straw		
No.		*Bu.*	*Lb.*	*Bu.*	*Lb.*	*Lb.*	*Bu.*	*Lb.*	*Bu.*	*Lb.*	*Lb.*	*No.*
1	None	41.40	2,351	15.17	1,699	3,205						1
2	Yard manure and floats	63.94	3,435	26.25	2,792	4,438	25.27	1,184	11.68	1,149	1.460	2
3	Stall manure and floats	66.62	3,611	27.86	3,037	4,765	30.67	1,461	13,87	1,450	2,013	3
4	None	33.23	2,049	13.40	1,531	2,526						4
5	Yard manure and acid phosphate	64.17	3,353	28.23	3,091	4,387	31.45	1,330	15.01	1,570	1,873	5
6	Stall manure and acid phosphate	66.84	3,540	28.79	3,232	4,917	34.64	1,543	15.77	1,722	2,414	6
7	None	31.68	1,972	12.84	1,501	2,492						7
8	Yard manure and kainit	57.41	3,234	23.53	2,593	3,619	24.80	1,243	10.64	1,072	1,076	8
9	Stall manure and kainit	62.02	3,433	24.84	2,854	4,229	28.49	1,423	11.87	1,313	1,635	9
10	None	34.45	2,030	13.02	1,561	2,645						10
11	None	39.97	2,355	16.22	1,871	3,421						11
12	Yard manure and gypsum	61.75	3,368	25.50	2,811	4,049	24.34	1,124	10.29	1,066	903	12
13	Stall manure and gypsum	61 84	3,438	25.66	2,816	4,046	26.99	1,305	11.47	1,197	1,177	13
14	None	32.28	2,021	13.17	1,493	2,596						14
15	Yard manure, untreated	53.93	2,916	22.53	2,477	3,514	19.44	794	9.26	957	840	15
16	Stall manure, untreated	59.83	3,230	23.81	2,653	4,115	23.13	1,008	10.44	1,106	1,363	16
17	None	38.90	2,322	13.47	1,573	2,830						17
18	Fertilizer*	48.89	2,676	18.35	2,040	3,220	11.66	457	5.16	472	398	18
19	Fertilizer†	45.49	2,475	17.41	2,049	3,309	9.93	358	4.52	486	495	19
20	None	33.90	2 013	12.61	1,557	2,807						20
	Average unmanured yield	35.73	2,139	13.72	1,582	2,815						

*No manure: acid phosphate, 80 lb.; muriate of potash, 80 lb.; nitrate of soda, 160 lb.
†No manure: acid phosphate, 200 lb.; muriate of potash, 10 lb.; nitrate of soda, 40 lb.
(Previous to 1918 same total elements, but nitrogen and part of phosphorus in tankage.

TABLE XXIII: Barnyard MANURE and chemical fertilizers on corn, followed by wheat and clover in rotation
Average yield per acre by periods

Plot No.	Manure and treatment	First period—3 rotations					Second period to 1918					Plot No.
		Corn 1897-1905		Wheat 1898-1906		Clover 1901-1907	Corn 1906-1918		Wheat 1907-1918		Clover 1908-1918	
		Grain	Stover	Grain	Straw		Grain	Stover	Grain	Stover		
		Bu.	*Lb.*	*Bu.*	*Lb.*	*Lb.*	*Bu.*	*Lb.*	*Bu.*	*Lb.*	*Lb.*	
1	None	40.10	2,284	11.18	1,346	2,363	42.37	2,402	18.16	1,963	3,740	1
2	Yard manure and floats	58.20	3,310	24.16	2,538	3,660	68.25	3,529	27.83	2,982	4,934	2
3	Stall manure and floats	61.97	3,614	25.76	2,716	4,293	70.11	3,609	29.43	3,277	5,065	3
4	None	34.84	2,108	9.83	1,111	1,771	32.02	2,005	16.08	1,846	3,006	4
5	Yard manure and acid phosphate	59.05	3,234	24.39	2,499	3,422	68.00	3,442	31.10	3,535	5,001	5
6	Stall manure and acid phosphate	62.28	3,522	25.26	2,689	4,212	70.25	3,554	31.44	3,640	5,336	6
7	None	34.28	2,060	8.78	1,025	1,728	29.73	1,906	15.88	1,858	2,978	7
8	Yard manure and kainit	54.23	3,154	20.26	2,221	2,922	59.79	3,294	25.99	2,872	4,062	8
9	Stall manure and kainit	58.80	3,466	22.36	2,553	3,711	64.43	3,409	26.67	3,079	4,559	9
10	None	35.83	2,120	9.96	1,153	2,016	33.42	1,962	15.31	1,866	3,045	10
11	None	39.63	2,440	12.18	1,498	2,685	40.23	2,291	19.25	2,151	3,890	11
12	Yard manure and gypsum	57.35	3,340	22.66	2,481	3,248	65.05	3,389	27.62	3,059	4,560	12
13	Stall manure and gypsum	59.40	3,556	22.39	2,470	3,172	63.68	3,349	28.11	3,076	4,606	13
14	None	35.71	2,098	8.83	990	1,669	29.75	1,964	16.43	1,871	3,187	14
15	Yard manure, untreated	51.43	2,936	17.20	1,921	2,409	55.80	2,901	26.53	2,893	4,217	15
16	Stall manure, untreated	57.13	3,362	18.87	2,102	3,069	61.83	3,130	27.52	3,066	4,781	16
17	None	38.77	2,381	9.31	1,121	1,982	38.99	2,278	16.59	1,912	3,369	17
18	Fertilizer*	44.74	2,628	11.82	1,404	2,699	52.01	2,667	23.24	2,516	3,552	18
19	Fertilizer†	45.19	2,501	13.56	1,565	2,842	45.72	2,455	20.30	2,411	3,607	19
20	None	36.72	2,106	9.61	1,212	2,216	31.78	1,943	14.86	1,816	3,182	20
	Average untreated	36.99	2,198	9 92	1,141	2,054	34.78	2,094	16.57	1,912	3,300	

*No manure: acid phosphate, 80 lb.; muriate of potash, 80 lb.; nitrate of soda, 160 lb.

†No manure: acid phosphate, 200 lb.; muriate of potash, 10 lb.; nitrate of soda, 40 lb.

TABLE XXIV.—Barnyard MANURE and chemical fertilizers on Corn, followed by Wheat and Clover in rotation. Values of total produce and of increase.

Plot No.	Manure and Treatment	Value Per Acre of Total Yields		Value of Increase Due to Treatment				Plot No.
				Per Acre		Per Ton Manure		
		First Period	Second Period	First Period	Second Period	First Period	Second Period	
1	None	$39.21	$52.00	$.....	$.....	$....	$....	1
2	Yard manure and floats	64.75	77.57	27.56	28.72	3.44	3.59	2
3	Stall manure and floats	70.70	80.54	35.54	34.84	4.44	4.35	3
4	None	33.16	42.55	..	.....	...	....	4
5	Yard manure and acid phosphate	64.17	80.78	31.48	38.68	3.93	4.83	5
6	Stall manure and acid phosphate.	69.94	83.69	37.71	42.03	4.71	5.25	6
7	None	31.76	41.22	.....	.....	....	....	7
8	Yard manure and kainit	56.34	68.77	23.79	27.08	2.97	3.38	8
9	Stall manure and kainit	64.00	73.54	30.29	31.40	3.78	3.92	9
10	None ..	34.70	42.60	.. ..	.....	....	....	10
11	None	41.49	52.64	.....	.....	....	....	11
12	Yard manure and gypsum	61.55	74.50	23.17	25.21	2.90	3.15	12
13	Stall manure and gypsum	62.16	74.48	26.88	28.54	3.36	3.57	13
14	None	32.16	42.61	.....	.....	....	....	14
15	Yard manure, untreated	50.29	67.66	17.00	23.37	2.12	2.92	15
16	Stall manure, untreated	57.37	73.63	22.94	27.65	2.87	3.45	16
17	None	35.58	47.67	.....	.....	....	....	17
18	Chemical fertilizer *	43.58	61.12	8.00	14.32	....	....	18
19	Chemical fertilizer †	45.61	55.05	10.00	11.13	....	....	19
20	None	35.61	42.06	.....	.....	....	....	20
	Average unmanured yields	35.39	45.42	.....	.....	....	....	

*No manure: acid phosphate, 80 lb.; muriate of potash, 80 lb.; nitrate of soda, 160 lb.

†No manure: acid phosphate, 200 lb.; muriate of potash, 10 lb.; nitrate of soda, 40 lb. (Previous to 1918 same quantities of elements, but nitrogen and part of phosphorus in tankage.)

In 1905 Section B in this test received a dressing of caustic lime, applied at the rate of a ton to the acre and spread over all the land, manured and unmanured alike, after the land had been plowed for corn. In 1906 and 1907 Sections A and C were dressed with ground limestone, used at the rate of two tons per acre and likewise spread over all the land after plowing for corn. In 1911 and since ground limestone has been applied to each section as it came under corn.

To this liming has been due the superior growth of clover during the second period of this test, as shown in Table XXIII, and in part, at least, that of wheat. The inferior yield of corn during this period has apparently been chiefly due to grub worms, which injured the crop so seriously in 1909 that no comparison could be made, and have caused some injury in other seasons.

It will be observed that all manure applications, treated and untreated, show a greater effect during the second period than during the first, the rate of gain being considerably greater in the case of the manure treated with acid phosphate than from any other treatment.

In computing the increase for Table XXIV it has been assumed that the variations in the natural yield of the land are probably progressive; that is, that the yields on Plot 1 for the first period being worth $39 and those on Plot 4, $33, the probability is that if Plots 2 and 3 had not been manured or fertilized their yields would have been $37 and $35, respectively. This method of computation shows a consistently larger increase from acid phosphate than from floats, although the total yields are about as large from the floats as from the acid phosphate. In the second period, however, the acid phosphate remains distinctly in the lead, although the larger quantity of phosphorus applied in the floats had led us to expect that as the floats had longer time in which to become available just the opposite outcome would be realized.

In Table XXV the four phosphated manures are compared directly with the untreated manures as applied to Plots 15 and 16, the comparison being made both on the total yields and on the increases. This table shows that while the effectiveness of the manures treated with acid phosphate has kept pace with those receiving no treatment, that of all the other treatments has relatively fallen behind.

The cost of treatment has not been deducted in the foregoing tables. At prices which had prevailed for several years before the European war the cost of floats delivered at average Ohio points was about $7.50 per ton in bulk carloads, and that of 14 percent acid phosphate, the grade used in this test, about $11.50, on the same basis of bulk carloads. Adding $2.50 per ton for hauling to the farm and applying, the cost of the floats, spread on the land, would be $1.60 per acre or 20 cents per ton of manure, and that of acid phosphate, $2.24 per acre or 28 cents per ton of manure. Present prices would be approximately double the prices used in these tables, both for fertilizers and produce, but this would not alter the comparative outcome.

TABLE XXV.—Barnyard MANURE on Corn, followed by Wheat and Clover in rotation. Value per acre of increase due to materials used in reinforcement of manure in excess of that produced by untreated manure.

Plot No.	Manure and Reinforcement.	Computed on Total Yields		Computed on Increase	
		First Period	Second Period	First Period	Second Period
2	Yard manure and floats	$14.46	$ 9.91	$10.56	$ 5.35
3	Stall manure and floats	13.33	6.91	12.59	7.19
5	Yard manure and acid phosphate	13.88	13.12	14.48	15.31
6	Stall manure and acid phosphate	12.57	10.06	14.77	14.38
8	Yard manure and kainit	6.05	1.11	6.79	3.71
9	Stall manure and kainit	6.63	.....	7.35	3.75
12	Yard manure and gypsum	11.26	6.84	6.17	1.84
13	Stall manure and gypsum	4.79	.85	3.94	.89

VIII: THE POTATOES-WHEAT-CLOVER ROTATION

This experiment is located on the South Farm, southeast of the orchards, and contains three sections of 34 plots each. The south section (A) and about half of the middle section (B) had been in cultivation for an unknown period before the test began. The north part of Section B and all of the north section (C) were cleared from the forest for the purposes of this test. The old land was tile drained in 1893, and the work was begun by planting Section A to potatoes in 1894. Wheat and clover followed in 1895 and 1896 and the rotation has been maintained regularly since.

The potato crops in this test in some seasons have been somewhat injured by blight, and in 1904 a dashing rain, coming just after the potatoes had been planted, washed much of the seed out of the ground. These difficulties have caused an irregular stand, and for this reason the attempt has been made to correct the yields on the basis of the average stand obtained on the unfertilized plots, but this method has not proved satisfactory and hence the actual yields are given in the table. In 1909 the potatoes were reduced to about one-third the average crop by a combined attack of white grub and Fusarium wilt, the latter causing the larger part of the injury. The crop was severely injured by wilt again in 1910 and considerably injured in 1911.

Because of the increasing tendency to disease in the potato crop during recent years the plan has been adopted of giving half the potato land to corn each year, and arranging the rotation so that potatoes will occupy the land every sixth season instead of every third season, this change beginning in 1917 on Section C, north half.

In 1895 and 1896 the wheat in this test was severely injured by Hessian fly, but it escaped the attack of 1899 to 1901. In 1911 there was again some injury from fly and joint worm.

In 1909 the clover failed; attempts were made to grow crimson clover and soybeans in its stead, but there was failure in securing a stand of these crops also, so that it has been necessary to omit that season from the calculations. In 1905 continuous rains prevented harvesting the clover until very late, and caused the fertilized plots to lodge so that these plots weighed less than those not fertilized, though earlier in the season they had shown a distinctly larger growth. As there was no way by which the yields could be corrected and as it seemed desirable to include the crop in the general average because of its effect on the average unfertilized yield it has been so included, although the doing so slightly reduces the apparent average effect from the fertilizers.

Diagram IV shows the arrangement of plots and plan of fertilizing one of the sections in this experiment, the three sections being arranged and treated alike. Tables XXVI to XXIX show the outcome for the 25 years, 1894-1918, and for 12-year periods.

A striking feature of this experiment is the apparent decrease in effectiveness for potatoes of acid phosphate and increase in that of muriate of potash during the last period as compared with the first, while for wheat acid phosphate maintains its lead.

DIAGRAM IV.—PLAN OF FERTILIZING IN POTATOES-WHEAT-CLOVER ROTATION.

PLOTS ONE-TENTH ACRE. Fertilizing Materials in Pounds Per Acre.

Plot No.	On Potatoes			On Wheat			
	Acid Phosphate	Muriate Potash	Nitrate Soda	Acid Phosphate	Muriate Potash	Dried Blood	Nitrate Soda
1	....	....	....	....	....	....	....
2	160	....	....	160	....	....	....
3	....	100	....	....	100	....	....
4	....	....	....	....	....	....	....
5	....	....	80	....	....	50	120
6	160	....	80	160	....	50	120
7	....	....	....	....	....	....	....
8	160	100	....	160	100	....	....
9	....	100	80	....	100	50	120
10	....	....	....	....	....	....	....
11	160	100	80	160	100	50	120
12	160	100	160	160	100	50	200
13	....	....	....	....	....	....	....
14	320	200	160	160	100	50	120
15	480	300	320	....	....	....	....
16	....	....	....	....	....	....	....
17	....	....	....	Manure, 4 tons on wheat			
18	....	....	....	Manure, 8 tons on wheat			
19	....	....	....	....	....	....	....
20	160	100	80	160	100	25	60
21	Same elements as 20, but nitrogen in oilmeal						
22	....	....	....	....	....	....	....
23	Same elements as 20, but nitrogen in dried blood						
24	Same elements as 20, but nitrogen in sulphate ammonia						
25	....	....	....	....	....	....	....
26	Same elements as 11, but phosphorus in bonemeal						
27	Same elements as 20, but nitrogen in nitrate of lime*						
28	....	....	....	....	....	....	....
29	Same elements as 11, but phosphorus in basis slag						
30	Manure, 8 tons on potatoes			....	....	....	....
31	....	....	....	....	....	....	....
32	....	....	....	Manure, 16 tons on wheat			
33	Same elements as 20, but nitrogen in tankage						
34	....	....	....	....	....	....	....

*Since 1910; previously same elements as 11.

TABLE XXVI: Yield and increase of POTATOES grown in rotation with wheat and clover

Plot No.	Fertilizing materials	25-year average 1894-1918		12-year average 1894-1905		12-year average 1906-1917		Plot No.
		Yield	Increase	Yield	Increase	Yield	Increase	
	Pounds per acre	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	
1	None	137.95		169.03		110.64		1
2	Acid phosphate, 160	145.91	7.67	190.29	18.40	107.67	—2.04	2
3	Muriate of potash, 100	154.45	15.91	180.78	6.01	135.25	26.45	3
4	None	138.83		177.63		107.87		4
5	Nitrate of soda, 80	144.97	8.43	179.57	6.55	118.17	10.61	5
6	Acid phosphate, 160; nitrate of soda, 80	151.72	17.47	189.35	20.94	119.51	12.26	6
7	None	131.97		163.80		106.93		7
8	Acid phosphate, 160; muriate of potash, 100	165.93	34.19	186.86	21.48	151.22	46.21	8
9	Muriate of potash, 100; nitrate of soda, 80	153.33	21.84	171.82	4.77	140.27	37.19	9
10	None	131.25		168.55		101.16		10
11	Acid phosphate, 160; muriate of potash, 100; nitrate of soda, 80	163.30	31.18	185.41	17.09	146.89	44.70	11
12	Acid phosphate, 160; muriate of potash, 100; nitrate of soda, 160	169.15	36.17	192.14	24.04	151.66	48.43	12
13	None	133.85		167.87		104.27		13
14	Acid phosphate, 320; muriate of potash, 200; nitrate of soda, 160;	173.56	42.07	190.38	25.99	159.51	56.50	14
15	Acid phospeate, 480; muriate of potash, 300; nitrate of soda, 320	169.54	40.40	187.37	26.45	154.41	52.65	15
16	None	126.78		158.39		100.50		16
17	Yard manure, 4 tons, on wheat only	*137.99	13.69	**172.05	11.57	117.00	15.66	17
18	Yard manure, 8 tons, on wheat only	*146.26	21.84	**176.38	16.72	128.65	26.47	18
19	None	126.46		153.13		103.02		19
20	Acid phosphate, 160; muriate of potash, 100; nitrate of soda, 80	165.29	39.16	193.64	36.92	144.93	42.34	20
21	Same elements as 20, but nitrogen in oilmeal	160.99	35.20	180.88	27.39	145.79	43.62	21
22	None	125.46		152.23		101.74		22
23	Same elements as 20, but nitrogen in dried blood	161.42	36.68	170.84	16.06	145.84	45.45	23
23	Same elements as 20, but nitrogen in sulphate of ammonia	162.55	38.54	189.87	32.52	146.54	47.51	24
25	None	123.29		159.91		97.68		25
26	Same elements as 11, but phosphorus in bonemeal	157.90	34.16	182.55	25.55	146.33	48.38	26
27	Same elements as 20, but nitrogen in nitrate of lime†	161.53	38.14	190.98	36.88	146.73	48.50	27
28	None	123.44		151.20		98.33		28
29	Same elements as 11, but phosphorus in basic slag	162.42	37.19	177.63	22.64	155.31	54.47	29
30	Yard manure, 8 tons, on potatoes only	171.21	44.19	188.44	32.78	158.65	55.46	30
31	None	128.81		162.58		105.54		31
32	Yard manure, 16 tons, on wheat only	‡178.69	56.52	§192.26	30.95	172.67	66.46	32
33	Same elements (since 1899) as 20, but nitrogen in tankage	‡158.63	32.14	§194.50	35.21	144.53	32.88	33
34	None	125.80		157.64		107.56		34
	Average unfertilized yield	129.45		165.81		103.85		

*23 years, 1896-1918. **10 years, 1896-1905. †Since 1910. Previously same as 11, but phosphorus in dissolved boneblack. ‡22 years, 1897-1918. §9 years, 1897-1905.

TABLE XXVII.--Yield and increase of WHEAT (grain only) in rotation with potatoes and clover.

Plot No.	Fertilizing Materials	24-Year Average 1895-1918		12-Year Average 1895-1906		12-Year Average 1907-1918		Plot No.
		Yield	Increase	Yield	Increase	Yield	Increase	
	Pounds Per Acre.	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	
1	None	29.96	.....	29.48	.....	30.45	.....	
2	Acid phosphate, 160	36.28	6.41	34.79	5.51	37.78	7.30	1
3	Muriate potash, 100	31.47	1 68	31.32	2.25	31.62	1.11	2
4	None	29.70	.....	28.85	.....	30.55	.....	3
5	Dried blood, 50; nitrate soda, 120	30.05	.90	29.47	1.07	30.63	.73	4
6	Acid phosphate, 160; dried blood, 50; nitrate soda, 120	36.42	7.83	35.08	7.15	37.75	8.50	5
7	None	28.03	.....	27.47	.....	28.60	.....	6
8	Acid phosphate, 160; muriate potash, 100	35.99	7.78	35.09	7.36	36.88	8.19	7
9	Muriate potash, 100; dried blood, 50; nitrate of soda, 120	33.06	4.68	33.58	5.60	32.54	3.76	8
10	None	28.56	.....	28.24	.....	28.87	.....	9
11	Acid phosphate, 160; muriate potash, 100; dried blood, 50; nit. soda, 120	38.23	9.88	37.28	9.24	39.18	10.51	10
12	Acid phosphate, 160; muriate potash, 100; dried blood, 50; nit. soda, 200	38.32	10.17	37.16	9.31	39.50	11.04	11
13	None	27.95	.....	27.64	.....	28.26	.....	12
14	Acid phosphote, 160; muriate potash, 100; dried blood, 50; nit. soda, 120	38.47	10.83	37.30	10.25	39.65	11.41	13
15	Fertilized on potatoes only	37.09	9.76	35.97	9.51	38.21	10.00	14
16	None	27.02	.....	25.87	.....	28.18	.....	15
17	Yard manure, 4 tons	31.95	5.92	29.58	4.65	34.32	7.17	16
18	Yard manure, 8 tons	33.88	8.83	30.43	6.45	37.32	11.21	17
19	None	24.06	.....	23.04	.....	25.07	.....	18
20	Acid phosphate, 160; muriate potash, 100; dried blood, 25; nitrate soda, 60	35.28	11.48	32.12	9.13	38.45	13.83	19
21	Same elements as 20, but nitrogen in oilmeal	34.42	10.86	32.85	9.91	35.99	11.81	20
22	None	23.31	.....	22.89	.....	23.72	.....	21
23	Same elcments as 20, but nitrogen in dried blood	34.85	11.38	33.66	10.59	36.03	12.18	22
24	Same elements as 20, but nitrogen in sulphate ammonia	35.22	11.60	33.27	10.01	37.18	13.20	23
25	None	23.78	.....	23.45	.....	24.11	.....	24
26	Same elements as 11, but phosphorus in bonemeal	34.92	11.05	34.28	10.77	35.57	11.33	25
27	Same elements as 20, but nitrogen in nitrate of lime*	36.60	12.63	35.49	11.91	37 71	13.35	26
28	None	24.07	.....	23.64	.....	24.49	.....	27
29	Same elements as 11, but phosphorus in basic slag	36.93	12.87	36.07	12.50	37.79	13.25	28
30	Manured on potatoes	31.89	7.85	30.34	6.85	33.44	8.86	29
31	None	24.02	.....	23.42	.....	24.62	.....	30
32	Yard manure, 16 tons	†37.88	12.34	‡37.52	11.00	38.18	13.45	31
33	Same elements as 20, but nitrogen in tankage	†37.26	11.83	‡37.71	11.57	36.89	12.05	32
34	None	†25.31	.....	‡25.75	.....	24.95	.....	33
								34
	Average unfertilized yield	26.19	.....	25.57	.....	26.82	.....	

*Since 1910. Previously, same as 11, but phosphorus in dissolved boneblack.
†22 years, 1897-1918.
‡10 years, 1897-1906.

TABLE XXVIII.—Yield and increase of CLOVER grown in rotation with potatoes and wheat.

Plot No.	Total fertilizing materials applied to previous crops of rotation. None on clover.	23-Year Average, 1896-1918		12-Year Average, 1896-1907		11-Year Average, 1908-1918		Plot No.
		Yield	Incre's	Yield	Incre's	Yield	Incre's	
	Pounds per Acre.	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	
1	None	4,034	.....	4,266	.....	3,892	.....	1
2	Acid phosphate, 320	4,266	296	4,404	315	4,174	238	2
3	Muriate potash, 200	4,042	137	3,949	39	4,205	225	3
4	None	3,841	.....	3,733	.....	4,025	.....	4
5	Nitrate soda, 200; dried blood, 50	4,211	396	3,927	205	4,558	604	5
6	Acid phosphate, 320; nitrate soda, 200; dried blood, 50	4,335	546	3,997	285	4,673	789	6
7	None	3,763	.....	3,702	.....	3,814	.....	7
8	Acid phosphate, 320; muriate potash, 200	4,043	353	3,915	235	4,210	502	8
9	Muriate potash, 200; nitrate soda, 200; dried blood, 50	4,191	574	4,100	441	4,244	643	9
10	None	3,544	.....	3,638	.....	3,493	.....	10
11	Acid phosphate, 320; muriate potash, 200; nitrate soda, 200; dried blood, 50	4,219	635	3,872	210	4,533	1,000	11
12	Acid phosphate, 320; muriate potash, 200; nitrate soda, 360; dried blood, 50	4,396	772	4,075	390	4,702	1,129	12
13	None	3,664	.....	3,709	.....	3,613	.....	13
14	Acid phosphate, 480; muriate potash, 300; nitrate soda, 280; dried blood, 50	4,355	755	4,045	415	4,627	1,064	14
15	Acid phosphate, 480; muriate potash, 300; nitrate soda, 320. On potatoes only	4,245	709	4,029	479	4,376	864	15
16	Nope	3,473	.....	3,470	.....	3,463	.....	16
17	Yard manure, 4 tons, on wheat only	4,182	801	3,957	566	4,369	999	17
18	Yard manure, 8 tons, on wheat only	4,569	1,278	4,267	954	4,837	1,559	18
19	None	3,199	.....	3,234	.....	3,186	.....	19
20	Acid phosphate, 320; muriate potash, 200; nitrate soda, 140; dried blood, 25	4,050	879	3,904	649	4,168	1,077	20
21	Same elements as 20, but nitrogen in oilmeal	3,634	491	3,494	217	3,661	666	21
22	None	3,115	.....	3,299	.....	2,900	.....	22
23	Same elements as 20, but nitrogen in dried blood	3,672	530	3,553	236	3,713	764	23
24	Same elements as 20, but nitrogen in sulphate ammonia	3,683	513	3,530	195	3,746	747	24
25	None	3,197	.....	3,353	.....	3,048	.....	25
26	Same elements as 11, but pho3phorus in bonemeal	4,023	748	3,852	481	4,111	935	26
27	Same elements as 20, but nitrogen in nitrate of lime*	3,906	551	3,676	286	4,083	780	27
28	None	3,433	.....	3,409	.....	3,430	.....	28
29	Same elements as 11, but phosphorus in basic slag	4,453	1,000	4,122	743	4,761	1,252	29
30	Yard manure, 8 tons, on potatoes only	4,358	900	4,124	775	4,574	986	30
31	None	3,470	.....	3,319	.....	3,666	.....	31
32	Yard manure, 16 tons, on wheat only†	‡5,081	1,661	‡4,616	1,296	5,443	1,868	32
33	Same elements (since 1899) as 20, but nitrogen in tankage†	†4,030	654	‡3,686	317	4,295	812	33
34	None†	†3 029	.....	‡3,417	.....	3 390	.....	34
	Average unfertilized yield	3 511	.....	3 556	.....	3,493	.....	

*Since 1910. Previously same as 11, but phosphorus in dissolved boneblack.
†21 years, 1898-1918.
‡10 years, 1898-1907.

TABLE XXIX.—Three-year rotation of POTATOES, WHEAT and CLOVER. Average value of increase for each rotation for 25 years and for periods of 12 years

Plot No.	Fertilizing materials in pounds per acre for each rotation	Cost of fertilizer for each rotation	Average value of total increase per acre for each rotation			Net gain or loss (—) from fertilizers for each rotation			Plot No.
			25 years 1894-1918	12 years 1894-1905	12 years 1906-1918	25 years 1894-1918	12 years 1894-1905	12 years 1906-1918	
2	Acid phosphate, 320	$ 2.60	$10.12	$13.58	$ 6.81	$ 7.52	$10.98	$ 4.21	2
3	Muriate of potash, 200	5.00	8.30	4.58	12.26	3.30	—0.42	7.20	3
5	Nitrate of soda, 200; dried blood, 50	7.20	5.99	4.41	7.63	—1.21	—2.79	.43	5
6	Acid phosphate, 320; nitrate of soda, 200; dried blood, 50	9.80	16.39	15.95	16.00	6.59	6.15	6.20	6
8	Acid phosphate, 320; muriate of potash, 200	7.60	21.91	16.16	27.77	14.31	8.56	20.17	8
9	Muriate of potash, 200; nitrate of soda, 200; dried blood, 50	12.20	11.23	8.75	20.99	— .97	—3.45	8.79	9
11	Acid phos., 320; mur. of potash, 200; nit. of soda, 200; dried blood, 50	14.80	24.08	16.00	31.93	9.28	1.20	19.13	11
12	Acid phos., 320; mur. of potash, 200; nit. of soda, 360; dried blood, 50	19.60	26.98	19.55	34.51	7.38	—0.05	14.91	12
14	Acid phos., 480; mur. of potash, 300; nit. of soda, 280; dried blood, 50	21.00	29.92	21.28	37.97	8.92	.28	16.97	14
15	Acid phos., 480; mur. of potash, 300; nit. of soda, 320; dried blood, 50	21.00	27.79	21.05	33.87	6.79	.05	12.87	15
17	Manure, 4 tons, on wheat	?	14.08	11.08	16.91	.....	.....	.....	17
18	Manure, 8 tons, on wheat	?	21.89	16.31	27.41	.....	.....	.....	18
20	Acid phos., 320; mur. of potash, 200; nit. of soda, 140; dried blood, 50	12.40	29.57	25.58	34.32	15.17	13.18	21.92	20
21	Same elements as 20, but nitrogen in oilmeal	12.40	25.85	20.74	31.09	13.45	8.34	18.69	21
23	Same elements as 20, but nitrogen in dried blood	12.40	26.98	19.27	32.32	14.58	6.87	19.92	23
24	Same elements as 20, but nitrogen in sulphate of ammonia	12.40	27.81	21.44	33.95	15.41	9.04	21.55	24
26	Same elements as 11, but phosphorus in bonemeal	14.80	27.60	19.60	33.59	12.80	4.80	18.79	26
27	Same elements as 20, but nitrogen in nitrate of lime*	12.40	28.92	22.95	34.95	16.52	10.55	22.55	27
29	Same elements as 11, but phosphorus in basic slag	14.80	30.47	21.94	39.13	15.67	7.14	24.33	29
30	Manure, 8 tons, on potatoes	?	28.32	22.38	34.15	.....	.....	.....	30
32	Manure, 16 tons, on wheat	?	40.62	27.46	46.94	.....	.....	.....	32
33	Same elements as 20, but nitrogen and part of phosphorus in tankage	12.40	25.96	22.36	27.25	13.56	9.96	14.85	33

*Since 1910. Previously, same elements as 11, but phosphorus in dissolved boneblack.

Table XXIX shows that there has been a marked increase in the rate of gain in this test when the fertilizer has carried potassium. Phosphorus alone in acid phosphate, shows a diminishing rate of increase (Plot 2) but when combined with potassium the increase, both total and net, is much greater than that from potassium alone (compare Plot 8 with Plot 3). Nitrogen seems to have comparatively little effect in this rotation, yet the increase on Plot 11 was abnormally small during the earlier years of the experiment. (Compare Plot 11 with Plots 20 to 29, inclusive.)

IX: THE 5-YEAR ROTATION AT STRONGSVILLE

The Strongsville farm is situated in southern Cuyahoga County, about 14 miles southwest of the public square in Cleveland. The land upon which this test is located slopes gently to the north, and overlies the argillaceous Cuyahoga shale from which the soil has been chiefly derived. The upper layers of the shale bear evidence of having been deposited as a mud in shallow water at a comparatively recent geologic period. The soil contains a much larger proportion of clay than at Wooster; hence it is more difficult to work, it dries out more slowly and suffers more from excess or deficiency of moisture. The native forest growth of this region consists chiefly of beech and elm, with sugar maple on the drier portions. The soil is classed as Trumbull clay loam, a type closely related to the Volusia clay loam, deficient in lime, and lying too flat to afford natural drainage and consequently being waterlogged until late in the spring. It represents that phase of the soils covering the northeastern counties of the state in which the ameliorations of drainage, liming and fertilizing are the most esesntial to successful agriculture.

In 1895 a 5-year rotation was begun on this farm, duplicating the one at Wooster, the object bein to study the same methods of treatment on two very dissimilar soils. The arrangement of plots in this test is shown in Diagram V.

Soon after the experiment was begun the land in Sections A, B, C and D was drained with tile drains laid 30 inches deep and under alternate dividing paths, but Section E was not drained until several years later.

As in the similar experiments at Wooster, no provision for the use of lime was made in the original plan of the test, but in 1901 the experiment was modified by applying lime to the south half of each section as it came under corn, the lime being used at first at the rate of 1 ton of quicklime, and later at 2 tons of ground limestone per acre and spread over all the land after plowing, fertilized and unfertilized alike; and 3 years later a further modification was made by spreading raw phosphate rock at the rate of 1 ton per acre across the north ends of the plots at the same time and in the same manner that the limestone was spread across the south ends.

This method of treatment has left no direct means of comparing the effect of limestone or phosphate rock with untreated land, except by comparing the yields since the change was made with those obtained previous to the change. It was difficult to provide a direct comparison without sacrificing some other point in the test.

During the first 17 years of this experiment there were nine failures of the timothy crop; the attempt to grow this crop was then abandoned and the soybean, grown for hay, was substituted in the rotation, which was so rearranged as to make the succession corn, oats, soybeans, wheat and clover, the soybeans being mown for hay. For this reason the timothy is omitted from the computations which follow, and the work is treated as a 4-year rotation of corn, oats, wheat and clover.

At the prices current before the outbreak of the European war finely-ground limestone was spread on the land at a cost of $3 per ton, representing an annual cost of $1.50 per acre for 2 tons spread during each 4-year period.

The cost of the phosphate rock during the same period amounted to $10 per ton spread on the land. The phosphate treatment was discontinued after the total dressing had amounted to 2½ tons per acre, thus making the annual acre cost for the 13 years equivalent to $1.90.

Table XXX gives the yields of the grain and hay harvested during the first 10 years of this experiment, or before the effect of the treatment with lime and floats became manifest, and for the period since, namely: 13 years for corn, 12 for oats, 11 for wheat and 10 for clover, together with the average annual value of produce, computing corn at half a dollar a bushel, oats at one-third of a dollar, wheat at one dollar and hay at eight dollars a ton, these prices for the grain alone being very nearly equivalent to the prices heretofore employed where both grain and stover or straw were computed.

In computing this table the average yield of all the unfertilized plots is taken as the basis and to this is added the increase produced by the different

treatments, this method giving a more accurate measure of the effect of treatment, where entire yields are used for comparison, than if the actual yields were employed.

The table shows that on the unfertilized land the yield of corn was a bushel larger, that of oats a bushel smaller, that of wheat twice as great and that of clover 50 percent larger on the limed land during the second period than it was during the first period when no liming was done.

This farm lies near the junction of the three counties, Cuyahoga, Lorain and Medina, and the statistics of crop production for these counties, as collected by the township assessors, show that the average yields for the three counties during the two periods covered by this test were nearly 1 bushel per acre greater during the second period than during the first for corn, about 2 bushels smaller for oats, and 1 bushel greater for wheat. As there was a considerable increase in the use of commercial fertilizers over these counties during the second period it seems probable that the larger yields found in this experiment were chiefly due to the treatment, rather than to seasonal variations.

Plot 30 in this experiment gave abnormal yields of corn during the first 15 years, a superiority which has since disappeared, leading to the belief that it was due to some temporary enrichment before the land came under experiment. Excluding this plot and also No. 27, on which the plan of fertilizing has recently been changed, we find that the average annual value of produce during the first 10 years of the test for the 14 plots receiving both nitrogen in other carriers than manure, and phosphorus, has been between $14 and $15 per acre, Plot 33, receiving 19 pounds of nitrogen giving as large a yield as Plot 12, receiving 114 pounds.

During the second period, however, the effect of nitrogen is more apparent, especially on the floats-treated land.

Taking the average unfertilized yield of the first 10 years as the standard, acid phosphate alone has increased the yield during that period by $4.64; liming has increased it during the next period by $2.16, and lime and acid phosphate by $8.14, while floats alone has increased the yield by $5.68.

Comparing Plots 5 and 6, which receive the same quantities of nitrogen in nitrate of soda, by the same methods, the yield of Plot 6, receiving acid phosphate also, has been $5.46 greater than that of Plot 5 during the first period; liming alone has increased the yield by $2.45 during the second period, lime and acid phosphate by $8.79, and floats alone by $6.22.

Comparing Plots 9 and 11, which receive the same quantities of nitrate of soda and muriate of potash, the yield of Plot 11, receiving acid phosphate in addition, has been $5.16 greater than that of Plot 9 during the first period; liming alone has increased the yield of Plot 9 by $2.61 during the second period; lime and acid phosphate (on Plot 11) by $9.78, and floats alone (on Plot 9) by $8.37.

The annual cost of treatment during this period has been approximately 64 cents per acre for acid phosphate, $1.50 for liming and $1.80 for the floats treatment. Deducting these costs, the net results are tabulated below, no account being taken of the cost of nitrogen and potassium.

Plot No.	Basic treatment	Value of total produce	Net value of increase for liming and phosphate treatment			
			Acid phosphate	Lime	Acid phosphate and lime	Floats
0	None	$8.54	$4.00	$0.66	$6.00	$3.78
5	Nitrate of soda	8.72	4.82	0.95	6.65	4.32
9	Nit. of soda and mur. of potash	9.35	4.52	1.11	7.64	6.47

It is evident that the raw phosphate rock has been used very profitably in this experiment, but that the combination of acid phosphate and limestone has been more profitable, even though its cost has been somewhat greater.

Manure does not appear to have been any more effective than nitrate of soda in making the phosphorus of the raw rock available. In this experiment,

however, the manure and floats have not been mixed together, the manure being first plowed under and the floats applied to the surface. The manure, however, is steadily increasing the organic matter in the soil, as shown by its darker color, and the timothy yields on Plot 18 have been nearly twice as great, and on Plot 39 more than twice as great as those on Plot 12, an outcome probably partly due to the timothy seed carried in the manure.

Potassium has not in any case increased the yield on this soil to a sufficient extent to justify its use in commercial form, even at the low prices prevailing before the European war, except when used in the small quantity applied on Plot 36, equivalent to about 14 pounds of muriate of potash annually, and this only during the second period.

The cost of the half-dressing of nitrate of soda on Plot 17, with its larger dressing of acid phosphate, has been barely recovered when the phosphorus was further increased by the floats dressing, but when the phosphorus has been reduced or the nitrate increased the cost of the nitrogen has been greater than the value of the increase. No other commercial carrier of notrogen has been as effective in proportion to cost as nitrate of soda.

DIAGRAM V.—ARRANGEMENT OF PLOTS IN 5-YEAR ROTATION AT STRONGSVILLE

Plots one-tenth acre

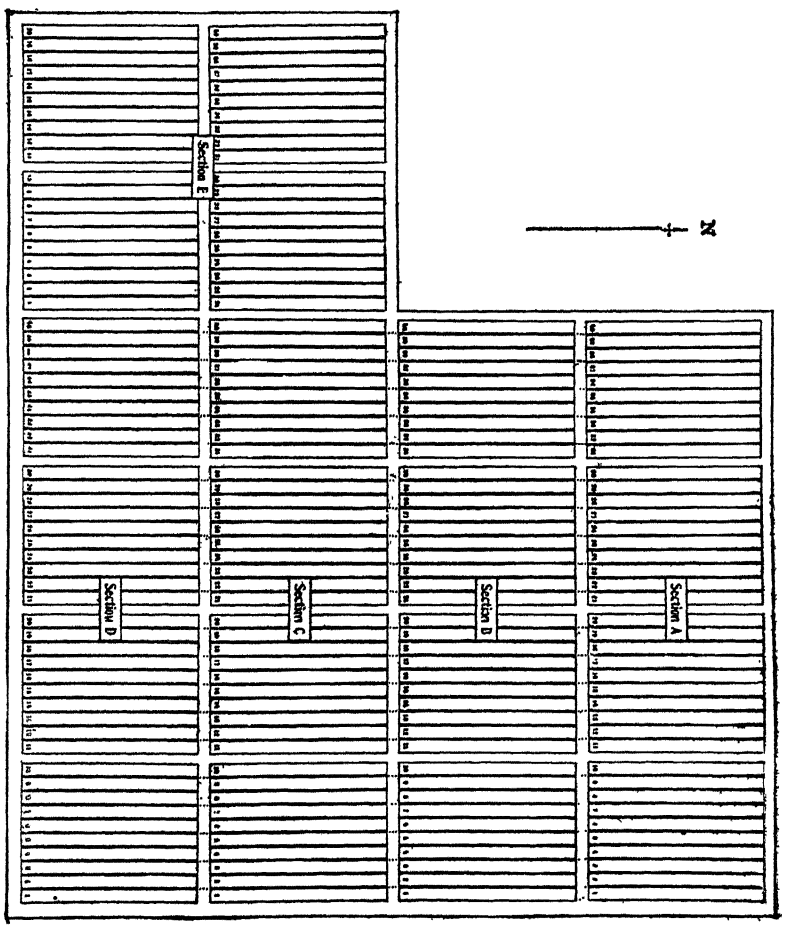


TABLE XXX.—The 5-year rotation at Strongsville. Effect of limestone and raw phosphate rock

Plot No.	Total fertilizing elements per acre for one 5-year rotation			Average annual yield per acre											Annual value of produce			Plot No.
				Corn			Oats			Wheat			Clover						
	Nitrogen	Phosphorus	Potassium	First period 1895-1904	Second period 1905-1918		First period	Second period		First period	Second period		First period	Second period		First period	Second period		
					Lime	Floats		Lime	Floats		Lime	Floats		Lime	Floats		Lime	Floats	
	Lb.	*Lb.*	*Lb.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Lb.*	*Lb.*	*Lb.*	$	$	$	
2	.....	20	.....	31.9	33.9	31.3	45.3	46.7	50.2	12.6	19.8	18.1	2,273	3,599	3,575	13.18	16.68	16.19	2
3	.....	.....	108	23.8	25.9	27 8	35.6	36.5	42.2	5.4	11.2	13.1	1,469	2,217	3,200	8.76	11.29	13.47	3
5	76	.....	.....	23.7	23.9	33.2	34.9	36.2	47.2	5.3	11.1	12.7	1,523	2,388	3,683	8.72	11.17	14.94	5
6	76	20	.....	32.8	34.3	37.0	49.7	48.3	52.1	15.2	24.0	23.6	2,145	3,199	3,845	14.18	17.51	18.71	6
8	.....	20	108	30.9	35.1	38.6	45.5	49.1	47.9	13.5	21.0	20.5	2,040	2,880	3,844	13.07	16.61	17.78	8
9	76	.....	108	24.2	23.2	39.1	36.5	40.9	50.9	7.2	13.1	19.3	1,488	2,381	3,764	9.35	11.96	17.72	9
11	76	20	108	34.4	37.0	36.1	49.6	51.3	54.3	15.7	23.9	24.4	2,154	3,237	3,992	14.51	18.13	19.13	11
12	114	20	108	33.3	39.6	38.1	49.6	51.9	55.3	18.3	25.5	25.2	2,084	3,264	3,901	14.95	18.91	19.57	12
14	50	15	74	32.0	29.5	38.1	40.3	37.5	48.0	16.3	23.1	24.0	2 078	2,992	3,883	13.51	15.58	18.64	14
15	25	10	41	29.1	24.7	32.8	34.8	33.7	46.5	14.8	22.2	22.3	1,866	3,715	3,587	12.10	14.16	17.14	15
17	38	30	108	33.0	39.5	40.8	50.3	49.0	53.7	14.2	23.9	22.7	2,152	3,289	4,346	14.02	18.28	19.59	17
18	128*	28*	96*	35.4	38.8	43.5	42.0	43.0	49.8	14.5	20.0	21.7	2,129	3,413	4,650	13.68	16.84	19.66	18
20	64†	14†	48†	30.6	34.3	36.6	38.8	40.5	46.7	10.4	17.2	18.2	1,978	3,063	4,023	11.63	15.02	17.04	20
21	38	30	108	31.9	39.9	36.7	49.7	48.3	51.0	15.1	23.0	20.7	2,299	3,000	3,303	14.20	17.76	17.31	21
23	38	30	108	33.4	37.5	37.4	49.6	47.7	52.5	15.1	21.8	21.7	2,184	3,150	3 608	14.26	17.26	18.08	23
24	38	30	108	32.4	36.7	33.8	50.7	49.1	53.9	15.8	21.9	22 0	2,132	3,463	3,444	14.36	17.62	17.66	24
26	76	20	108	31.7	35.2	38.7	48.5	47.5	55.5	16.5	21.5	22.6	2,349	3,566	3,771	14.48	17.30	18.88	26
27	76	20	108	31.2	34.5	36.8	49.7	49.3	51.9	15.8	22.7	20.2	2,044	3,219	3,578	14.03	17.31	17.55	27
29	76	20	108	34.8	36.6	40.3	49.6	48.4	54.2	16.9	23.9	22.1	2,173	3,123	3,944	14.88	17.70	19.02	29
30	38	30	103	40.2	43.3	40.7	52.1	50.4	52.2	17.1	23.2	22.7	2,543	3,609	3,814	16.18	18.89	18.92	30
32	36	20	108	33.7	34.7	38.0	50.0	49.3	52.7	15.2	23.4	20.9	2,267	3,231	3 785	14.20	17.52	18.15	32
33	19	20	108	34.4	35.8	35 8	48.5	48.1	52.7	14.4	23.0	19.8	2,402	3,304	3,827	14.34	17.53	17.64	33
35	76	20	54	31.4	37.1	40.7	50.4	51.8	57.6	15.6	24.9	23.2	2,193	3,476	3,986	14.22	18.65	19.67	35
36	76	20	27	34.5	33.0	39.7	48.8	49.4	54.9	16.6	24.5	24.1	2,408	3 448	4,002	14.94	17.81	19.56	36
38	5½	12	5	30.8	30.4	31.2	37.9	35.9	42.7	14.4	20.8	19.2	2,204	3 064	3,630	12.81	15.05	15.89	38
39	128*	28*	26*	30.6	35.6	35.8	37.2	41.4	45.9	12.1	20.7	21.0	2 086	3 881	4,901	12.03	16.95	18.45	39
Average unfertilized yield.....				23.2	24.2	30.2	34.8	33.9	42.8	5.5	11.1	14.4	1 369	2 077	3 294	8.54	10.70	14.22	

*In 16 tons yard manure. †In 8 tons yard manure.

X: THE TOBACCO-WHEAT-CLOVER ROTATION AT GERMANTOWN

The experiment farm at Germantown is located on the divide between the Miami River and Twin Creek. The soil has been derived from the weathering of glacial drift, and this in turn has consisted largely of limestone detritus, so that the soil was originally well supplied with lime.

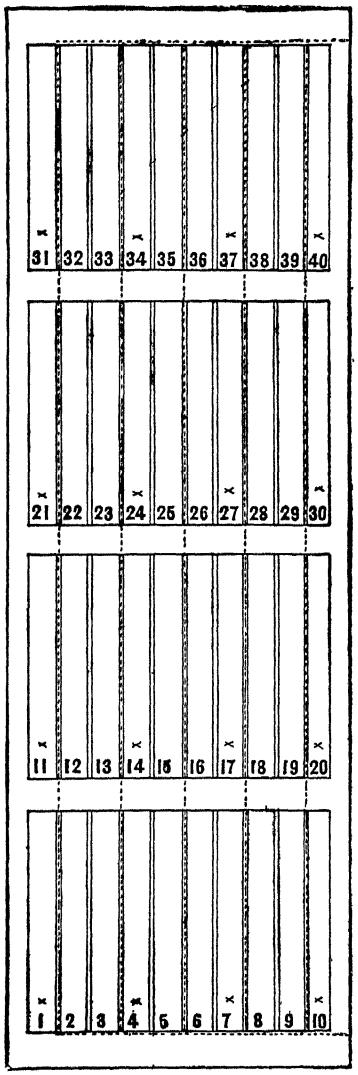


DIAGRAM VI.—Arrangement of plots in tobacco-wheat-clover rotation Sections B and C

Tobacco has been a leading crop in this region for many years. Corn and wheat have been extensively grown, in a more or less systematic rotation with clover, the corn being chiefly fed to hogs, which had been pastured on clover, while the wheat was sold to the flouring mills or elevators, and the wheat straw to the paper mills that were located at frequent intervals along the Miami canal.

In 1903 a 3-year rotation of tobacco, wheat and clover was begun on the experiment farm, under the plan of fertilizing shown in Table XXXI, three tracts of land being employed, each containing 40 one-twentieth acre plots, arranged as shown in Diagrams VI and VII. The results of this work for the 16 years, 1903 to 1918, are given in Tables XXXII and XXXIII.

These tables show that although potassium has been indispensable to the attainment of the highest yield, yet it has been necessary that the potassium should be associated with phosphorus.

Nitrogen in nitrate of soda or sulphate of ammonia has caused a further increase over that given by clover, but the nitrogen in tankage and manure has been less effective.

The muriate of potash has apparently been more effective than the sulphate or nitrate.

The greatest total increase and the greatest net gain are found on the three plots numbered 13, which receive on each tobacco crop a total dressing of 720 pounds of acid phosphate, 180 pounds of muriate of potash and 240 pounds of nitrate of soda per acre.

On these plots the tobacco has averaged 1,274 pounds per acre for 16 years, the wheat which follows the tobacco without any fertilizing, 28.57 bushels, and the clover 4,804 pounds. The net value of the increase, at the low prices used in this computation (tobacco, 8 cents a pound; wheat, 80 cents a bushel; wheat straw, $2 a ton; clover hay, $8 a ton) has amounted to $65.80 per acre for the 3 crops of each rotation, no account being taken of the extra cost of harvesting the larger yields, which is comparatively small.

DIAGRAM VII.—ARRANGEMENT OF PLOTS IN TOBACCO-WHEAT-CLOVER ROTATION

Section A

Plots one-twentieth acre

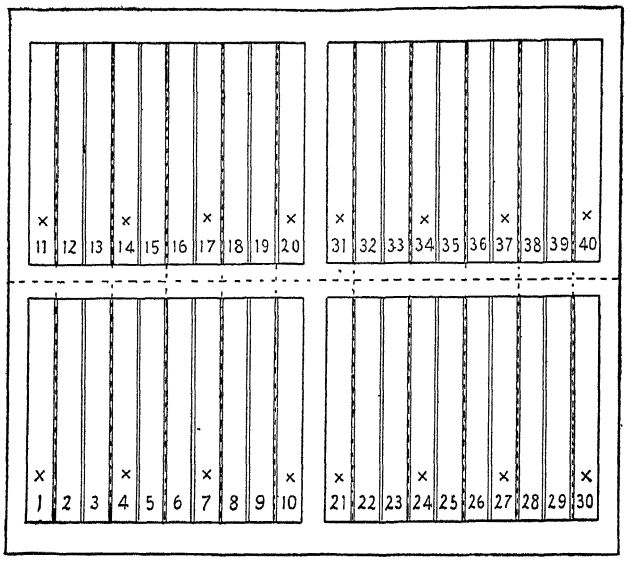


TABLE XXXI.—Plan of fertilizing TOBACCO grown in rotation

Plot No.	Fertilizing materials per acre (All applied to the tobacco crop)	Fertilizing elements per acre		
		Phosphorus	Potassium	Nitrogen
		Lb.	*Lb.*	*Lb.*
1	None			
2	Acid phosphate, 480 lb.	30		
3	Acid phosphate, 480 lb.; muriate potash, 180 lb.	30	75	
4	None			
5	Muriate potash, 180 lb.; nitrate soda, 240 lb.		75	38
6	Acid phosphate, 480 lb.; nitrate soda. 240 lb.	30		38
7	None			
8	Acid phos., 480 lb.; mur. potash, 180 lb.; nit. soda, 240 lb.	30	75	38
9	Acid phos., 480 lb.; mur. potash, 300 lb.; nit. soda, 240 lb.	30	125	38
10	None			
11	None			
12	Acid phos., 480 lb.; mur. potash, 120 lb.; nit. soda, 240 lb.	30	50	38
13	Acid phos., 720 lb.; mur. potash, 180 lb.; nit. soda, 240 lb.	45	75	38
14	None			
15	Acid phos., 480 lb.; mur. potash, 180 lb.; nit. soda, 360 lb.	30	75	57
16	Acid phos., 480 lb.; mur. potash, 180 lb.; sulph. ammonia, 180 lb.	30	75	38
17	None			
18	Acid phos., 60 lb.; tankage (7-20) 670 lb.; muriate potash, 180 lb.	30	75	38
19	Acid phos., 320 lb.; mur. potash, 180 lb.; nit. soda, 240 lb.	20	75	38
20	None			
21	None			
22	Acid phos., 480 lb.; nitrate potash, 200 lb.; nit. soda, 80 lb.	30	75	38
23	Acid phos., 480 lb.; sulphate potash, 190 lb.; nit. soda, 240 lb.	30	75	38
24	None			
25	Acid phos., 480 lb.; sul. potash, 190 lb.; nit. soda, 240 lb.; lime, 1,000 lb.	30	75	38
26	Acid phos., 480 lb.; mur. potash, 180 lb.; nit. soda, 240 lb.; lime, 1,000 lb.	30	75	38
27	None			
28	Acid phos., 480 lb.; mur. potash, 180 lb.; sul. am., 180 lb.; lime. 1,000 lb.	30	75	38
29	Acid phos., 60 lb.; tankage (7-20) 670 lb., mur. pot., 180 lb.; lime, 1,000 lb.	30	75	38
30	None			
31	None			
32	Shed manure, untreated, 10 tons			
33	Shed manure, untreated, 20 tons			
34	None			
35	Shed manure, phosphated, 10 tons			
36	Yard manure, phosphated, 10 tons			
37	None			
38	Shed manure, untreated, 10 tons; lime, 1,000 lb.			
39	Yard manure, untreated, 10 tons; lime 1,000 lb.			
40	None			

TABLE XXXII.—TOBACCO, WHEAT and CLOVER grown in 3-year rotation at Germantown.

Average Annual Yield and Increase per Acre 1903-4-5-1918.

Plot No.	Tobacco 1903-1918		Wheat—1904-1918				Clover 1905-1918		Plot No.
			Grain		Straw				
	Yield	Increase	Yield	Increase	Yield	Increase	Yield	Increase	
	Lb.	*Lb.*	*Bu.*	*Bu.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	
1	559	...	11.48	.....	1,512	.....	2,729	.....	1
2	789	240	21.54	9.98	2,728	1,203	3,910	1,208	2
3	1,105	574	25.13	13.48	3,041	1,503	4,423	1,748	3
4	516	...	11.73	.....	1,550	.....	2,649	.....	4
5	733	193	16.12	3.92	1,974	374	3,299	560	5
6	1,012	449	25.65	12.97	3,166	1.517	4,274	1,446	6
7	587	...	13.14	.....	1,699	.....	2,919	.....	7
8	1,227	656	26.63	14.09	3,296	1,669	4,416	1,632	8
9	1,217	662	27.52	15.59	3,174	1,621	4,533	1,883	9
10	538	...	11.33	.....	1,480	.....	2,517	.....	10
11	526	...	11.74	.....	1,577	.....	2,876	.....	11
12	1,141	617	25.28	13.53	3,203	1,622	4,234	1,378	12
13	1,274	752	28.57	16.81	3,402	1,817	4,804	1,968	13
14	521	...	11.78	.....	1,588	.....	2,815	.....	14
15	1,194	696	26.89	15.16	3,419	1,837	4,217	1,419	15
16	1,098	623	25.82	14.14	3,102	1,526	4,149	1,368	16
17	451	...	11.63	.....	1,569	.....	2,764	.....	17
18	960	506	26.16	1,503	2,997	1,494	4,360	1,629	18
19	1,027	571	25.27	1,463	2,971	1,533	4,025	1,326	19
20	459	...	10.15	.....	1,372	.....	2,665	.....	20
21	536	...	10.51	.....	1,376	.....	2,465	.....	21
22	1,131	600	25.15	14.67	3,075	1,698	3,897	1,509	22
23	1,127	602	25.09	14.63	3,049	1,670	4,058	1,747	23
24	521	...	10.44	.....	1,380	.....	2,234	.....	24
25	1,074	574	26.32	1,577	3,217	1,855	4,075	1,842	25
26	1,069	589	27.78	1.711	3,335	1,992	4,139	1,907	26
27	459	...	10.78	.....	1,325	.....	2,231	.....	27
28	1,082	626	28.05	17.46	3,311	1,976	4,193	1,934	28
29	959	505	23.96	13.57	2,824	1,479	4,084	1,798	29
30	451	...	10.21	.....	1,354	.....	2,314	.....	30
31	522	...	10.24	.....	1,363	.....	2,159	.....	31
32	993	480	22.71	12.51	2,810	1,433	3,585	1,417	32
33	1,140	637	27.32	17.16	3,458	2,066	4,131	1,954	33
34	493	...	10.12	.....	1,407	.....	2,187	.....	34
35	1,065	589	26.69	1,668	3,213	1,859	4,312	2,102	35
36	892	434	24.34	1,445	2,921	1,620	3,713	1,479	36
37	441	...	9.79	.....	1,247	.....	2,257	.....	37
38	915	483	24.40	14.82	2,939	1,703	3,694	1,579	38
39	769	347	20.20	10.83	2,444	1,219	3,303	1,330	39
40	412	...	9.16	.....	1,214	.....	1,830	.....	40
*	499	...	10.89	.....	1,438	.....	2,484	.....	
†	1,041	...	25.11	.....	3,055	.....	4,070	.....	

*Average unfertilized yields.
†Average fertilized yields.

TABLE XXXIII.—TOBACCO-WHEAT-CLOVER ROTATION
Average increase, cost of fertilizer and net gain per acre

Plot No.	Fertilizing elements per acre			Average increase per acre				Cost of fertilizers	Total value of increase	Net gain	Plot No.
	Phosphorus	Potassium	Nitrogen	Tobacco 16-year average	Wheat, 15-yr. average		Clover 14-year average				
					Grain	Straw					
	Lb.	*Lb.*	*Lb.*	*Lb.*	*Bu.*	*Lb.*	*Lb.*	*Dollars*	*Dollars*	*Dollars*	
2	30	.....	.....	240	9.98	1,203	1,208	3.90	33.22	29.32	2
3	30	75	.....	574	13.48	1,503	1,748	8.40	65.20	56.80	3
5	.....	75	38	193	3.92	374	560	11.70	21.19	9.49	5
6	30	.....	38	449	12.97	1,517	1,446	9.10	53.60	44.50	6
8	30	75	38	656	14.09	1,669	1,632	15.60	71.95	56.35	8
9	30	125	38	662	15.59	1,621	1,883	18.60	74.58	55.98	9
12	30	50	38	617	13.53	1,622	1,378	14.10	67.32	53.22	12
13	45	75	38	752	16.81	1,817	1,968	17.50	83.30	65.80	13
15	30	75	57	696	15.16	1,837	1,419	19.20	75.32	56.12	15
16	30	75	38	623	14.14	1,526	1,368	15.60	68.52	52.55	16
18	30	75	38	506	15.03	1,494	1,629	13.90	60.51	46.61	18
19	20	75	38	571	14.63	1,533	1,326	14.30	64.22	49.92	19
22	30	75	38	600	14.67	1,698	1,509	15.60	67.47	51.87	22
23	30	75	38	602	14.63	1,670	1,747	16.50	68.52	52.02	23
25	30	75	38	574	15.77	1,855	1,842	19.50	67.76	48.26	25
26	30	75	38	589	17.11	1,992	1,907	18.60	70.42	51.82	26
28	30	75	38	626	17.46	1,976	1,934	18.60	73.76	55.16	28
29	30	75	38	505	13.57	1,479	1,798	16.90	59.93	43.03	29
32	.....	.....	.....	480	12.51	1,433	1,417	5.00	55.51	50.51	32
33	.....	.....	.....	637	17.16	2,066	1,954	10.00	74.57	64.57	33
35	.....	.....	.....	589	16.68	1,859	2,102	8.20	70.73	62.53	35
36	.....	.....	.....	434	14.45	1,620	1,479	8.20	53.82	45.62	36
38	.....	.....	.....	483	14.82	1,703	1,579	8.00	58.52	50.52	38
39	.....	.....	.....	347	10.83	1,219	1,330	8.00	42.96	34.96	39

Clover in wheat stubble on limed (left) and unlimed (right) ends of plots in 5-year rotation at Wooster

XI: LIMING THE TOBACCO CROP

The data concerning the effect of lime in this rotation are arranged in two periods in Table XXXIV, and show that on this land tobacco has been apparently indifferent to lime, and wheat and clover have only shown a distinct response to lime during the later years of the work.

It must be remembered, however, that this test is conducted on Miami clay loam, a soil originally well stocked with lime.

TABLE XXXIV.—Lime on **TOBACCO, WHEAT** and **CLOVER** in rotation at Germantown

Plot No.	Treatment	Increase Per Acre					
		First Two Rotations			Last Three Rotations		
		Tobacco 6 Crops	Wheat 6 Crops	Clover 6 Crops	Tobacco 9 Crops	Wheat 8 Crops	Clover 8 Crops
		Lb.	*Bu.*	*Lb.*	*Lb.*	*Bu.*	*Lb.*
8	Acid phos., mur. pot., nit. soda.	624	10.59	1,386	710	16.49	1,816
26	Acid phos., mur. pot., nit. so., lime	619	12.75	1,396	500	20.02	2,289
	Increase or decrease (—) for lime.	—5	2.26	10	—120	3.53	473
23	Acid phos., sul. pot., nit. soda...	563	11.35	1,347	642	16.81	2,053
25	Acid phos., sul. pot., nit. so., lime	578	12.19	1,282	585	18.16	2,262
	Increase or decrease (—) for lime.	15	.84	—65	-57	1.35	209
16	Acid phos., mur. pot., sul. am...	688	11.72	1,208	612	15.74	1,488
28	Acid phos., mur. pot., sul. am. lime	618	12.72	1,613	644	20.61	2,175
	Increase or decrease (—) for lime	—70	1.00	405	32	4.86	687
18	Tankage, muriate potash.....	445	12.54	1,302	580	16.82	1,874
29	Tankage, muriate potash, lime.	507	8.56	1,568	518	16.67	1,970
	Increase or decrease (—) for lime.	62	—3.08	266	—62	—.15	96
32	Untreated shed manure.....	433	10.40	1,194	514	13.96	1,585
38	Untreated shed manure, lime...	447	10.50	1,080	521	17.70	1,952
	Increase or decrease (—) for lime	15	.10	—114	7	3.74	367
	Average unfertilized yield	576	10.66	2,112	477	11.04	2,344

Unfertilized Fertilized

XII: TOBACCO GROWN CONTINUOUSLY ON THE SAME LAND

The plan of this experiment and the average results for 16 years are given in Table XXXV. The table shows that it has been possible to maintain fair yields of tobacco on mineral fertilizers alone, and that at the relative prices of tobacco and such fertilizers prevailing before the European war, tobacco might be grown in this way with profit.

Analysis of the tobacco plant shows that it contains nitrogen and potassium in approximately equal quantities, and the most effective fertilizer has conformed to this suggestion, as seen by comparing Plots 2 and 3 and 8 and 9. It seems to have been necessary to add phosphorus in much larger proportion than the analysis of the crop would indicate, but this is in general harmony with experience on other crops.

Manure has been a less effective fertilizer for tobacco than the chemical fertilizers employed in this test, in proportion to the chemical elements contained, but yet it may be much the cheapest fertilizer, if its cost is only that of hauling out and spreading. The experiment shows that a large part of the profit in the manure may be lost before it gets to the field.

TABLE XXXV.—TOBACCO grown continuously on the same land at Germantown

Plot No.	Annual treatment per acre				Averages for 16 years, 1903-1918					Pl't No.
	Acid phosphate	Muriate potash	Nitrate soda	Untreated shed manure	Yield per acre	Increase per acre	Cost of treatment	Value of increase	Net gain	
	Lb.	*Lb.*	*Lb.*	*Tons*	*Lb.*	*Lb.*	*Dollars*	*Dollars*	*Dollars*	
1	.....	.....	.....	.....	332	.....	.....	.....	.....	1
2	160	60	80	.....	695	347	5.20	27.76	22.56	2
3	160	60	160	.....	787	424	7.60	33.92	26.32	3
4	.....	.....	.....	.....	379	.....	.....	.....	.....	4
5	160	60	320	.....	916	555	12.40	44.40	32.00	5
6	160	60	480	.....	891	548	17.20	43.84	26.64	6
7	.....	.....	.....	.....	325	.....	.....	.....	.....	7
8	320	60	320	.....	1,017	699	13.70	55.92	42.22	8
9	320	120	320	.....	1,064	753	15.20	60.24	45.04	9
10	.....	.....	.....	.....	304	.....	.....	.....	.....	10
11	.....	.....	.....	8	806	.....	.....	.....	.....	11
12	160	.....	.....	8	940	129	1.28	10.32	9.04	12
13	160	60	160	8	1,091	273	7.58	21.84	14.22	13
14	.....	.....	.....	8	823	.....	.....	.....	.....	14
15	160	60	320	8	1,144	264	11.58	21.12	9.54	15
16	Phosphated shed manure, 5 T			8	1,192	253	?	20.24	?	16
17	.....	.....	.....	8	995	.....	.....	.....	.....	17
18	Phosphated yard manure, 5 T			8	1,153	158	?	12.64	?	18
Average unfertilized plots: 1, 4, 7 and 10..					348	.....	.....	.....	.....	
Average manured plots: 11, 14 and 17.....					875	527	?	42.16	?	

Note: For Plots 11 to 18 the increase is computed over the yields produced by manure alone, on Plots 11, 14 and 17. The yield on these plots shows an average increase for 8 tons of manure of 527 pounds of tobacco over the average unfertilized yields on Plots 1, 4, 7 and 10.

XIII:..THE CORN-WHEAT-CLOVER ROTATION AT GERMANTOWN

The plan of this experiment is shown in Table XXXVI. Previous reports have been made in Bulletins 182, 184 and 206. Table XXXVII gives the average yields and increase for the 15 years, 1904-1918, and Table XXXVIII shows the financial outcome, computing crops and fertilizing materials at the valuations heretofore employed (see page 596) and rating untreated manure at 50 cents and phosphated manure at 75 cents a ton, the manure being phosphated by mixing with it about 40 pounds of raw phosphate rock to the ton of manure during accumulation.

This table indicates that on this soil and at pre-war prices phosphorus in acid phosphate has increased the yield by more than 4 times its cost, and that potassium in the muriate, when added to phosphorus in the small quantity of 7 to 13 pounds of the muriate annually, has been used as profitably as the phosphate, as shown by comparing Plot 3 with Plot 2 and Plot 11 with Plot 9, although here as elsewhere the support of phosphorus has been necessary to the effectiveness of potassium, as shown by Plot 5, and by comparing Plots 23 and 26 with Plots 24 and 27, although the effect of manure and of reinforcing it with floats has not been as marked in this experiment as in the similar one at Wooster. The first 16 years of the Wooster experiment, as reported in Circular 144, are compared below with the 15-year period at Germantown:

Manure and treatment	Net value of increase per ton of manure	
	Wooster	Germantown
Yard, untreated	$2.60	$1.68
Yard, and floats	3.54	2.21
Shed, untreated	3.31	2.89
Shed, and floats	4.47	2.94

While there seems to be but little difference in the demand for phosphorus on the Germantown and Wooster soils the call for nitrogen seems to be much more urgent at Wooster. For example, the 240 pounds of 14-percent acid phosphate applied during each 3-year rotation at Germantown has produced increase to the value of $10.39, or $4.33 for 100 pounds of acid phosphate, while during the first 16 years of the 5-year rotation at Wooster 320 pounds of the same grade of acid phosphate produced increase to the value of $16.52, or $5.02 for 100 pounds of acid phosphate. But at Germantown 160 pounds of nitrate of soda, added to the dressing of acid phosphate, has increased the value of the yield by $2.83, or $1.77 for 100 pounds of nitrate, while at Wooster 480 pounds of nitrate added to the phosphate has increased the yield by $14.80, or $3.01 for 100 pounds of nitrate. These facts may explain in part the lower effect of manure at Germantown than at Wooster.

There seems to be no evidence that the addition of lime has as yet increased the yield to a sufficient extent to have paid its cost in this experiment.

TABLE XXXVI.—Plan of fertilizing in CORN-WHEAT-CLOVER rotation at the Germantown Test Farm.

Plot No.	Fertilizing Materials—Pounds Per Acre								Fertilizing Elements—Pounds Per Acre		
	On Corn			On Wheat				Total Fertilizers for One Rotation			
	Acid Phosphate	Muriate of Potash	Nitrate of Soda	Acid Phosphate	Muriate of Potash	Dried Blood	Nitrate of Soda		Phosphorus	Potassium	Nitrogen
1	...	..	...	...	...	...	...	...	...	...	...
2	120	...	...	120	...	...	...	240	15	...	...
3	120	20	...	120	20	...	...	280	15	16	...
4	...	...	...	...	...	...	...	...	...	...	...
5	...	20	80	...	20	30	60	210	...	16	25
6	120	...	80	120	...	30	60	410	15	...	25
7	...	...	...	...	...	...	...	...	...	...	...
8	120	20	80	120	20	30	60	450	15	16	25
9	120	20	160	120	20	30	140	610	15	16	50
10	...	...	...	...	...	...	...	...	...	...	...
11	120	40	160	120	40	30	140	650	15	32	50
12	240	20	80	240	20	30	60	710	30	16	25
13	...	...	...	...	...	...	...	...	...	...	...
14	240	40	160	240	40	30	140	890	30	32	50
15	480	80	320	Lime, 1,000 pounds				890	30	32	50
16	...	...	...	...	...	...	...	...	...	...	...
17	Untreated shed manure 5 tons on corn; lime, 1,000 lbs. on wheat.										
18	Untreated shed manure 10 tons, 1904-5-6; lime, 1,000 lbs., 1917-8-9; manure and lime on corn only*										
19	....	....	....	....	....	....	....	....	....	....	....
20	Untreated shed manure 10 tons, 1903-4-5; lime, 1,000 lbs., 1906-7-8; manure and lime on wheat only*										
21	Lime, 1,000 lbs. on corn; untreated shed manure, 5 tons on wheat.										
22	Unfertilized.										
23	Untreated yard manure, 5 tons, on corn only.										
24	Untreated shed manure, 5 tons, on corn only.										
25	Unfertilized.										
26	Phosphated yard manure, 5 tons on corn only.										
27	Phosphated shed manure, 5 tons on corn only.										
28	Unfertilized.										
29	Phosphated shed manure, 5 tons on corn; lime, 1,000 lbs. on wheat.										
30	Tankage, 680 lb.; muriate of potash, 80 lb.; nitrate of soda, 80 lb. on corn; lime, 1,000 lb. on wheat.										
31	Unfertilized.										
32	Tankage, 340 lbs.; muriate of potash, 40 lb.; nitrate of soda, 40 lb. on corn; same on wheat.										
33	Tankage, 340 lb.; muriate of potash, 60 lb.; nitrate of soda, 120 lb. on corn; same on wheat.										
34	Unfertilized.										
35	Tankage, 220 lb.; acid phos., 200 lb., muriate of potash, 20 lb. on corn; same on wheat.										
36	Tankage, 220 lb.; acid phos., 200 lb.; muriate of potash, 40 lb.; nitrate of soda, 80 lb. on corn; same on wheat.										
37	Unfertilized.										
38	Tankage, 500 lb.; muriate of potash, 60 lb.; nitrate of soda, 60 lb. on corn; same on wheat.										
39	Tankage, 170 lb.; nitrate of soda, 18 lb. on corn; same on wheat.										
40	Unfertilized.										

*The use of lime and manure on alternate rotations has been continued.

Table XXXVI shows that acid phosphate, when used alone at the rate of 120 pounds per acre each on corn and wheat, has produced a profitable increase in each crop, as well as in the clover following, the total value of the increase amounting to more than 4 times the cost of the fertilizer.

TABLE XXXVII.—CORN, WHEAT and CLOVER grown in 3-year rotation at Germantown. Average annual yield and increase per acre 1904 to 1918.

Plot No.	Corn, 15 Years				Wheat, 14 years				Clover 14 Years		Plot No.
	Grain		Stover		Grain		Straw				
	Yield	Increase	Yield	Increase	Yield	Increase	Yield	Increase	Yield	Increase	
	Bu.	*Bu.*	*Lb.*	*Lb.*	*Bu.*	*Bu.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	
1	36.45	.....	1,920	.....	8.42	.....	1,052	.....	2,266	.....	1
2	44.45	6.75	2,216	255	13.93	5.11	1,596	488	2,977	684	2
3	51.21	12.27	2,525	522	16.27	7.05	1,825	661	3,149	831	3
4	40.19	.....	2,044	.....	9.63	.....	1,220	.....	2,344	.....	4
5	44.17	4.49	2,243	218	10.78	1.51	1,279	111	2,472	141	5
6	46.71	7.55	2,364	359	16.11	7.19	1,986	872	3,078	760	6
7	38.64	.....	1,985	.....	8.56	.....	1,062	.....	2,305	.....	7
8	52.95	14.01	2,556	549	18.46	9.67	2,108	992	3,110	789	8
9	52.86	13.62	2,565	535	18.37	9.36	2,211	1,040	3,124	789	9
10	39.54	.....	2,052	.....	9.23	.....	1,225	.....	2,351	.....	19
11	59.50	17.86	2,986	829	20.69	11.07	2,453	1,220	3,502	1,110	11
12	59.91	16.17	3,112	850	22.22	12.21	2,510	1,269	3,904	1,472	12
13	45.85	.....	2,367	.....	10.40	.....	1,249	.....	2,472	.....	13
14	62.27	18.49	3,126	857	24.40	14.43	2,867	1,654	3,636	1,237	14
15	63.01	21.31	3,428	1,256	19.03	9.50	2,293	1,117	3,578	1,252	15
16	39.63	.....	2,075	.....	9.11	.....	1,140	.....	2,253	.....	16
17	59.83	18.55	3,117	962	14.52	5.10	1,858	667	3,090	762	17
18	59.50	16.58	3,169	935	15.24	5.52	1,925	684	3,043	675	18
19	44.57	.....	2,313	.....	10.03	.....	1,292	.....	2,488	.....	19
20	50.70	9.89	2,533	506	15.96	6.43	1,950	709	3,316	833	20
21	48.02	8.42	2,373	321	16.67	7.63	2,078	888	3,607	1,128	21
22	37.10	.....	1,921	.....	8.55	.....	1,140	.....	2,473	.....	22
23	47.31	11.37	2 289	391	10.65	2.38	1,351	245	2,671	278	23
24	52.58	17.80	2 588	715	12.60	4.61	1,584	511	2,872	519	24
25	33.62	.....	1,849	.....	7.70	.....	1,039	.....	2,356	.....	25
26	50.75	14.25	2,529	592	12.50	4.25	1,504	399	2,829	413	26
27	57.45	18.08	2,901	878	14.63	5.83	1,693	523	3,038	490	27
28	42.25	.....	2,110	.....	9.36	.....	1,235	.....	2,692	.....	28
29	60.87	19.05	3,283	1,174	16.51	6.97	2,066	786	3,540	886	29
30	58.43	17.05	3,103	994	17.23	7.51	2,156	832	3,806	1,100	30
31	40.94	.....	2,109	.....	9.90	.....	1,369	.....	2,713	.....	31
32	57.89	16.98	2,863	737	21.58	11.72	2,611	1,255	3,959	1,182	32
33	56.46	15.60	3 047	904	22.41	12.59	2,744	1,402	3,995	1,154	33
34	40.82	.....	2.159	.....	9.78	.....	1,329	.....	2,905	.....	34
35	55.40	14.63	2,928	732	20.82	11.44	2,392	1,108	3,825	1,072	35
36	55.62	14.91	3,017	785	22,21	13,22	2,598	1,359	3,744	1,144	36
37	40.65	.....	2,269	.....	8.59	.....	1,193	.....	2,447	.....	37
38	55.52	15.21	3,096	871	20.23	11.93	2,434	1,304	3,427	1,003	38
39	46.07	6.10	2.393	212	11.45	3.43	1,414	351	2,780	379	39
40	39.63	.....	2,137	.....	7.74	.....	1,000	.....	2,377	.....	40
41	39.73	5.14	1,984	253	8.22	—.21	1,321	120	3,408	758	41
	39.99	.....	2,094	.....	9.07	.....	1,181	.....	2,460	....	
	63.67	.....	2,754	....	16.80	.....	2,030	.....	3,314	....	

TABLE XXXVIII.—Fertilizers, manure and lime on CEREAL crops grown in rotation at Germantown. All calculated for one acre for 3 years

Plot No.	Fertilizing elements			Lime	Total value of increase	Cost of treatment	Net gain or loss (—)	Plot No.
	Phosphorus	Potassium	Nitrogen					
	Lb.	*Lb.*	*Lb.*	*Lb.*	*Dollars*	*Dollars*	*Dollars*	
2	15	.....	.....	.....	10.39	1.90	8.49	2
3	15	16	.....	.....	15.32	2.90	12.42	3
5	.....	16	25	.....	4.01	5.80	—1.79	5
6	15	.....	25	.....	13.22	6.70	6.52	6
8	15	16	25	.....	18.31	7.70	10.61	8
9	15	16	50	.....	17.63	12.50	5.43	9
11	15	32	50	.....	22.90	13.50	9.40	11
12	30	16	25	.....	24.67	9.60	15.07	12
14	30	32	50	.....	26.83	15.40	11.43	14
15	30	32	50	1,000	24.13	18.40	5.73	15
17	*15	*45	*50	1,000	16.66	5.50	11.16	17
18	*15	*45	*50	1,000	15.83	5.50	10.33	18
20	*15	*45	*50	1,000	13.90	5.50	8.40	20
21	*15	*45	*50	1,000	15.35	5.50	9.85	21
23	†10	†35	†40	.....	8.40	2.50	5.90	23
24	*15	*45	*50	.....	14.47	2.50	11.97	24
26	‡20	‡35	‡40	.....	12.04	3.75	8.29	26
27	§25	§45	§50	.....	15.70	3.75	11.95	27
29	§25	§45	§50	1,000	19.29	6.75	12.54	29
30	30	32	50	1,000	19.55	18.40	1.15	30
32	30	32	50	.....	23.26	15.40	7.86	32
33	30	50	75	.....	23.69	21.20	2.49	33
35	44	16	25	.....	21.50	11.50	10.00	35
36	44	32	50	.....	23.65	17.30	6.35	36
38	44	50	75	.....	22.25	24.40	—2.15	38
39	15	.....	25	.....	7.37	6.70	0.67	39

*In untreated shed manure. †In untreated yard manure. ‡In phosphated yard manure. §In phosphated shed manure.

XIV: THE CORN-WHEAT-CLOVER ROTATION AT CARPENTER

The Carpenter farm is located in the northwestern quarter of Meigs County, about 15 miles south of Athens. It lies south of the glaciated area, and its soil is a typical Dekalb silt loam, formed by the decomposition of the shales and sandstones of the barren coal measures. This region of the state is so hilly that it is difficult to find land sufficiently level for plot experiments, and the work on this farm is limited to three sections of 20 plots each devoted to a 3-year rotation of corn, wheat and clover.

This experiment was begun at the same time as the one at Germantown, and the plan of fertilizing is a duplicate of the first 20 plots in the cereal rotation there. The yields and increase from treatment are given for the 15 years, 1904-1918, in Table XXXIX and the financial results are shown in Table XL.

The principal differences in the outcome in the two tests are a smaller effect of potassium and a larger effect of lime at Carpenter than at Germantown. The difference in effect of lime is easily explained by the geological history of the two soils, the Germantown soil having been derived from gravel that was chiefly of limestone origin, while the Carpenter soil is the residuum from the weathering of non-calcareous rocks.

The fact that the Carpenter farm had been for many years a cattle farm, most of the produce of which had been fed on the land, while the one at Germantown had been used in the production of tobacco, and of grain in a system of farming under which the grain and most of the straw had been removed from the land, the grain being sold or fed to hogs and the straw sold to the paper mills, may be an explanation of the greater demand for potassium on this farm than on the other.

TABLE XXXIX.—CORN, WHEAT and CLOVER grown in 3-year rotation at Carpenter. Average annual yield and increase per acre, 1904-1918.

Plot No.	Corn, 15 Years				Wheat, 14 Years				Clover, 14 years		Plot No.
	Grain		Stover		Grain		Straw		Hay		
	Yield	Increase	Yield	Increase	Yield	Increase	Yield	Increase	Yield	Increase	
	Bu.	*Bu.*	*Lb.*	*Lb.*	*Bu.*	*Bu.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	
1	32.27	.....	1,703	.....	10.08	.....	1,010	.....	1,330	.....	1
2	39.17	8.41	1,848	198	15.86	5.76	1,514	529	1,667	339	2
3	39.08	9.84	1,923	328	17.61	7.47	1,734	774	1,866	540	3
4	27.73	.....	1,542	.....	10.16	.....	936	.....	1,325	.....	4
5	30.12	1.37	1,696	102	11.76	1.38	1,125	150	1,389	16	5
6	37.12	7.37	1,814	166	18.17	7.58	1,817	804	1,942	456	6
7	30.76	.....	1,700	.....	10.81	.....	1,053	.....	1,566	.....	7
8	42.24	12.79	2,026	391	20.60	10.41	2,023	1,044	2,222	725	8
9	41.46	13.32	2,002	431	20.36	10.80	2,130	1,225	2,117	689	9
10	26.83	.....	1,506	.....	8.94	.....	831	.....	1,358	.....	10
11	39.25	12.58	1,884	392	20.55	10.96	2,128	1,203	2,113	681	11
12	40.19	13.67	1,911	433	23.66	13.42	2,325	1,305	2,319	813	12
13	26.37	.....	1,464	.....	10.89	.....	1,115	.....	1,580	.....	13
14	43.88	17.51	2,009	554	26.42	15.79	2,634	1,564	2,616	1,095	14
15	45.46	19.07	2,086	639	22.65	12.30	2,329	1,305	2,847	1,513	15
16	26.40	.....	1,438	.....	10.08	.....	980	.....	1,403	.....	16
17	39.26	12.72	1,901	446	17.62	8.18	1,734	816	2,210	952	17
18	41.79	15.09	1,960	488	17.00	8.20	1,584	728	1,938	738	18
19	26.85	.....	1,489	.....	8.16	.....	793	.....	1,212	.....	19
20	36.78	10.77	1,818	355	18.03	9.87	1,891	1,098	2,471	1,341	20
*	28.18	....	1,548	.....	10.09	.....	959	.....	1,395	.....	

*Average unfertilized yield.

TABLE XL.—CORN, WHEAT and CLOVER grown in 3-year rotation at Carpenter. Fertilizing elements applied, value of increase, cost of treatment and net gain, all per acre

Plot No	Phosphorus	Potassium	Nitrogen	Lime	Total Value of Increase	Cost of Treatment	Net Gain or loss (—)	Plot No.
	Lb.	*Lb.*	*Lb.*	*Lb.*	$	$	$	
2	15	..	..	.....	10.15	1.90	8.25	2
3	15	16	..	.....	13.34	2.90	10.44	3
5	..	16	25	.. .	2.02	5.80	—3.78	5
6	15	..	25	.....	11.89	6.70	5.19	6
8	15	16	25	.....	17.97	7.70	10.27	8
9	15	16	50	.....	18.60	12.50	6.10	9
11	15	32	50	.....	18.32	13.50	4.82	11
12	30	16	25	.....	21.41	9.60	11.81	12
14	30	32	50	.....	26.41	15.40	11.01	14
15	30	32	50	1,000	25.78	18.40	7.38	15
17	*15	*45	*50	1,000	16.93	5.50	11.43	17
18	*15	*45	*50	1,000	17.01	5.50	11.51	18
20	*15	*45	*50	1,000	19.20	5.50	13.70	20

*In untreated shed manure.

XV: THE CORN-OATS-WHEAT-CLOVER ROTATION AT FINDLAY

This experiment was begun in 1909 in a field of 20 acres that had formerly been used as a fairground, but which was leased to the Experiment Station for experiment purposes. The soil of the part of the field devoted to fertility experiments is the yellow Miami clay loam. It was not practicable to underdrain the land until after the work had been in progress for several years, and this fact, together with the irregularities due to the former use of the land, has caused considerable variation in the yield independently of the treatment given, but the frequent repetition of check plots has made it possible to reach some conclusions that may be safely accepted.

The plan of fertilizing and average yields thus far attained are given in Table XLII, and in Table XLI is shown the financial outcome, using the valuations heretofore employed; all calculations being for one rotation of 4 years.

TABLE XLI.—The CORN-OATS-WHEAT-CLOVER rotation at Findlay. Value of increase, cost of treatment and net gain per acre, 1904-1918.

Plot No.	Fertilizing Materials Per Acre				Total Value of Increase	Cost of Treatment	Net Gain	Plot No.
	Acid Phosphate	Muriate of Potash	Nitrate Soda	Lime				
	Lb.	*Lb.*	*Lb.*	*Lb.*	$	$	$	
2	360	..	...	.....	13.48	2.88	10.60	2
3	360	60	...	... .	15.12	4.38	10.74	3
5	...	60	160	... .	11.24	6.30	4.94	5
6	360	..	160	.....	15 51	7.68	7.83	6
8	360	60	160	.....	12.74	9.18	3.56	8
9	360	60	160	2,000	17.51	15.18	2.39	9
11	A	..	...	... .	23.58	5.00	18.58	11
12	240	B	...	2,000	21.64	10.42	11.22	12
14	240	A	...	.....	28.92	6.92	22.00	14

*The combined dressing of nitrate of soda and dried blood is computed as equivalent to 80 lb. nitrate of soda.

A. Untreated manure, 10 tons per acre.

B. Untreated manure, 5 tons per acre.

There seems to be no reason to doubt the usefulness of acid phosphate and manure on this land, and it appears to have been worth while to use the phosphate in addition to a moderate use of manure. Apparently manure is a much cheaper source of nitrogen and potassium than chemical fertilizers, if its cost be only that of moving it from the barnyard to the field. Lime appears to have been of some benefit, but not enough to justify its cost in the quantity used in these tests.

It is possible that a single dressing of lime on such land as this might be worth while, but it is evidently unprofitable to repeat the liming so frequently as has been found necessary on the sandstone soils of eastern Ohio.

TABLE XLII.—The CORN-OATS-WHEAT-CLOVER rotation at Findlay
Plan of fertilizing and average yield and increase per acre

Fertilizing materials; Pounds per acre

Plot No.	On corn				On oats			On wheat				Pl't No.
	Acid phosphate	Muriate of potash	Nitrate of soda	Lime	Acid phosphate	Muriate of potash	Nitrate of soda	Acid phosphate	Muriate of potash	Dried blood	Nitrate of soda	
1												1
2	120				120			120				2
3	120	20			120	20		120	20			3
4												4
5		20	40			20	40		20	30	60	5
6	120		40		120		40	120		30	60	6
7												7
8	120	20	40		120	20	40	120	20	30	60	8
6	120	20	40	2,000	120	20	40	120	20	30	60	9
10												10
11	*							*				11
12	*			2,000	120			120				12
13												13
14	120	*						120				14

*Untreated manure, 5 tons per acre.

Average yield and increase per acre

Plot No.	Corn, 9 years*		Oats, 9 years		Wheat, 5 years		Clover 5 years	Plot No.
	Grain Bu.	Stover Lb.	Grain Bu.	Straw Lb.	Grain Bu.	Straw Lb.	Lb.	
Average yield per acre								
1	23.73	1,663	27.60	1,542	5.40	792	1,556	1
2	30.41	1,972	33.88	1,911	10.27	1,416	2,284	2
3	35.39	2,364	33.68	1,894	11.85	1,415	2,587	3
4	28.54	2,017	29.41	1,497	6.37	945	1,589	4
5	36.56	2,447	32.88	1,726	10.73	1,484	2,732	5
6	40.06	2,518	37.74	2,159	14.85	1,774	2,675	6
7	31.30	2,216	31.35	1,691	9.19	1,280	2,258	7
8		2,507	36.25	2,036	14.33	1,785	2,760	8
9	37.21	2,486	38.54	2,169	14.50	1,799	3,036	9
10	40.26	2,123	31.25	1,518	7.60	1,060	1,801	10
11	29.16	2,711	38.75	2,087	17.00	2,309	3,300	11
12	43.41	2,737	43.09	2,256	13.50	1,851	3,086	12
13	46.48	2,202	34.06	1,567	7.08	947	1,723	13
14	33.03	2 677	41.11	2,131	19.87	2,297	3,981	14
	45. 32							
†	29.15	2,044	30.73	1,331	7.13	982	1,746	
Average increase per acre								
2	5.08	191	5.68	394	4.55	573	716	2
3	8.46	466	4.87	383	5.80	521	1,008	3
5	7.10	364	2.83	164	3.42	427	920	5
6	9.68	369	7.04	533	6.60	605	640	6
8	6.62	322	4.93	402	5.67	578	654	8
9	10.39	332	7.26	593	6.37	665	1,082	9
11	12.96	561	6.56	553	6.56	1,286	1,525	11
12	14.74	561	9.97	705	6.24	866	1,337	12
14	12.28	474	7.05	564	12.79	1,350	2,258	14

*1909-1917, the crop of 1918 having failed.
†Average unfertilized yield.

XVI: SUPPLEMENTAL FERTILITY TESTS AT WOOSTER

In 1915 a new rotation was begun on leased land adjoining the Station at Wooster, having for its object the study of some of the questions that have been raised in the older work.

One question that has frequently been raised by farmers visiting this older work has been whether the same expenditure of money in acid phosphate alone might not have produced a greater net gain than that recovered when the more expensive carriers of nitrogen and potassium were added to the phosphate. Another question has been whether it is better to distribute the fertilizer over all the crops of the rotation, or whether it may as well all be given to a single crop, and if the latter to which crop. Other questions relate to the ratio between the different elements in the fertilizer; to the relative effectiveness of the elements in manure and chemicals, and to the possibility of replacing the fertilizing materials in ordinary use with other carriers of the essential elements of fertility.

Realizing the impossibility of answering all the questions that suggest themselves, an experiment was begun in 1915, the plan of which is shown in Table XLIII, and the average results in Table XLIV.

This experiment has been in progress only 4 years, so that the crops have not yet come under the full plan and therefore the results shown in the table are certain to be considerably modified by the time another rotation is finished.

Where mixed fertilizers are used on Plots 5 to 18 the total quantity is brought up to 1,000 pounds by the addition of dry earth, to facilitate distribution and to show uniformity in formulas.

The fertilizers and crops are computed at prices prevailing before the European war. At these prices it would seem, at this stage of the work, to be better to put part of this expenditure for fertilizers into nitrogen and potassium, rather than to put it all in phosphorus; but present prices for carriers of potassium of course put this element out of the running.

In this first round, the concentration of the whole application of fertilizers on the wheat crop has been more profitable than to distribute it over the other crops, but this is probably partly due to seasonal conditions especially favorable to wheat. The four crops of wheat thus far grown have averaged 26 bushels per acre on land receiving no fertilizer nor manure, and this yield has been increased to nearly 42 bushels by 1,000 pounds of a 2-8-2 fertilizer; to 38½ bushels by 500 pounds each on corn and wheat, and to 36 bushels by 332 pounds each on corn, oats and wheat. The increase in the other crops in the rotation has made the concentration of all the fertilizer on wheat the more profitable method. This is in harmony with the common experience that crops of high acre value will usually justify larger expenditure for fertilizing than those of low acre value. It is interesting, however, to note that the same treatment which has increased the wheat yield by 16.91 bushels, or 65 percent of the unfertilized yield (Plot 11), has raised the corn yield by but 15.57 bushels, or less than 30 percent of the unfertilized yield, while at normal prices a bushel of wheat is worth more than twice as much as a bushel of corn.

The Calcined and Duplex Basic phosphates are products resulting from attempts to make the phosphorus of phosphate rock available without acidulation. Thus far they have proved considerably less effective in this experiment than acid phosphate, which is also true of the comparison between feldspar potash and the muriate.

Calcium cyanamid (Plot 24) has been slightly less effective than nitrate of soda (Plot 17).

The manure used in this experiment has been taken from a shed in which stock cattle had been kept, and has been used on the assumption that it should contain as much as 11 pounds of ammonia, 4½ pounds of phosphoric acid and 7½ pounds of potash to the ton of manure, but the outcome shows that the manure has thus far produced a considerably smaller increase than chemical fertilizers carrying ammonia, phosphoric acid and potash, in quantities equivalent to those which would be carried in the manure applications on the basis of these estimates.

TABLE XLIII.—SUPPLEMENTAL FERTILITY TESTS at Wooster: Fertilizing materials per acre for one rotation; essential constituents and crops fertilized.

Pounds Per Acre.

Plot No.	Fertilizing materials for one rotation				Essential constituents			Crops fertilized				Plot No.
	Nitr'te of soda	Acid phosphate	M'riate of potash	Cost	Ammonia	Phosphoric acid	Potash	Corn	Oats	Wheat	Clover	
1	....	....	....	$....	....	....	....	....	....	....	....	1
2	....	1,000	....	8 00	....	160	....	250	250	250	250	2
3	....	750	80	8.00	....	120	40	207	207	207	207	3
4	....	....	....	....	....	....	....	....	....	....	....	4
5	108	500	40	8.25	20	80	20	162	162	162	162	5
6	108	500	40	8.25	20	80	20	215	215	215	....	6
7	....	....	....	....	....	....	....	....	....	....	....	7
8	108	500	40	8.25	20	80	20	324	....	324	....	8
9	108	500	40	8.25	20	80	20	648	....	....	....	9
10	....	....	....	....	....	....	....	....	....	....	....	10
11	108	500	40	8.25	20	80	20	....	....	648	....	11
12	108	500	40	8.25	20	80	20	....	....	....	648	12
13	....	....	....	....	....	....	....	....	....	....	....	13
14	108	750	40	10.25	20	120	20	449	....	449	....	14
15	216	750	40	13.50	40	120	20	503	....	503	....	15
16	....	....	....	....	....	....	....	....	....	....	....	16
17	216	500	80	12.50	40	80	40	398	....	398	....	17
18	216	500	160	14.50	40	80	80	438	....	438	....	18
19	....	....	....	....	....	....	....	....	....	....	....	19
20	216	a	80	12.50	40	80	40	*	....	*	....	20
21	216	b	80	14.50	40	120	40		....	*	....	21
22	....	....	....	....	....	....	....		....	....	....	22
23	210	500	c	12.50	40	80	40	*	....	*	....	23
24	d	500	80	12.50	40	80	40		....	*	....	24
25	....	....	....	....	....	....	....	....	....	....	....	25
26	245	112	58	9.70	44	18	29	415	....	....	....	26
27	245	592	58	13.54	44	94	29	895	....	....	....	27
28	....	....	....	....	....	....	....	....	....	....	....	28
29	e	....	....	....	44	18	29	e	....	....	....	29
30	e	480	....	....	44	94	29	e	....	....	....	30
31	....	....	....	....	....	....	....	....	....	....	....	31
32	f	480	....	....	88	112	58	e	....	e	....	32
33	f	480	....	....	88	112	58	f	....	....	....	33
34	....	....	....	....	....	....	....	....	....	....	....	34
35	f	480	....	....	88	112	58	....	....	f	....	35
36	f	480	....	....	88	112	58	....	....	....	f	36
37	....	....	....	....	....	....	....	....	....	....	....	37
38	f	768	....	....	88	250	58	f	....	....	....	38
39	f	480	g	....	88	112	78	f	....	....	....	39
40	....	....	....	....	....	....	....	....	....	....	....	40

a Calcined or "Duplex Basic" phosphate equivalent to 500 lb. acid phosphate.*
b Calcined or "Duplex Basic" phosphate equivalent to 750 lb. acid phosphate.*
c Feldspar potash equivalent to 80 lb. muriate of potash.*
d Calcium cyanamid equivalent to 216 lb. nitrate of soda.*
e 4 tons shed manure.†
f 8 tons shed manure.†
g 160 lb. kainit.
*a, b, c and d are divided equally between corn and wheat.
†Manure is plowed under for corn and spread as a topdressing for wheat. The acid phosphate is spread on manured sod for corn and drilled with the wheat. Plots 30 and 33 receive manure and phosphate only on corn; Plot 35 only on wheat and Plot 36 only on the new seeding of clover after the wheat is harvested.

TABLE XLIV.—Crops grown in 4-year rotation. Fertilizer experiments

Fertililizing constituents				Average Yield Per Acre. Corn		Oats		Wheat		Clover	
Plot No.	Ammonia	Phos. acid	Potash	Grain	Stover	Grain	Straw	Grain	Straw	Hay	Plot No.
	Lb.	*Lb.*	*Lb.*	*Bu.*	*Lb.*	*Bu.*	*Lb.*	*Bu.*	*Lb.*	*Lb.*	
1	.....	.....	.....	56.15	2,492	64,36	2 746	27.14	2,999	4,151	1
2	.....	160	.....	66.34	2,892	66.51	2,995	33.66	3,063	4,999	3
3	.....	120	40	64.76	2,910	71.25	3.143	33.62	3,045	5,135	3
4	.....	.....	.....	56.22	2,605	63.59	2.415	25.50	2,550	4,095	4
5	20	80	20	65.00	2,807	67.16	2,717	34.28	3,535	4,838	5
6	20	80	20	66.68	2,755	66.98	2,847	36.10	3,073	4,453	6
7	.....	.....	.....	55.58	2,482	63.82	2,574	23.97	2 412	3,701	7
8	20	80	20	69.09	2,877	67.66	2,841	38.48	3,496	4,367	8
9	20	80	20	71.09	3,032	69.87	3,014	27.67	2,640	4,027	9
10	.....	.....	.....	55.49	2,510	64.03	2.606	25.55	2,614	3,790	10
11	20	80	20	57.45	2,490	64.11	2,608	41.89	3,808	4,856	11
12	20	80	20	56.03	2,437	61.11	2,309	24.10	2,206	4,599	12
13	.....	.....	.....	50.39	2,200	61.59	2,305	23.84	2,244	3,505	13
14	20	120	20	64.88	2,805	67.00	2,829	37.91	3,555	4,441	14
15	40	120	20	66.84	2,850	66.22	2,871	40.09	3,594	4,486	15
16	.....	.....	.....	53.48	2,685	62.73	2,392	24.28	2,273	3,727	16
17	40	80	40	66.04	2.865	67.89	2,947	39.91	3,617	4,353	17
18	40	80	80	66.30	2.887	67.60	2,850	40.43	3,811	4,394	18
19	.....	.....	.....	52.35	2,342	64.32	2,618	25.75	2,247	3,698	19
20	40	80	40	64.25	2,840	67.63	2,809	39.30	3,619	4,284	20
21	40	120	40	66.53	2,875	70.13	3 056	41.92	4,037	4,610	21
22	.....	.....	.....	56.36	2,462	62.81	2,597	27.53	2,650	3,727	22
23	40	80	40	66.06	2,837	66.41	2,885	39.30	3,732	4,495	23
24	40	80	40	71.00	3,092	66.74	2,804	38.89	3,426	4,530	24
25	.....	.....	.....	58.85	2,490	63.31	2,571	26.10	2,431	3,822	25
26	44	18	29	63.55	2,690	65.34	2,859	28.89	2,608	3,908	26
27	44	94	29	68.25	2,925	69.35	3,227	31.55	2,892	4,003	27
28	.....	.....	.....	58.36	2,515	61.67	2,810	29.29	2.820	3,671	28
29	44	18	29	62.01	2,732	60.96	2,939	29.34	4,692	3,680	29
30	44	94	29	66.87	2,805	64.71	2,856	30 06	2,676	3,695	30
31	.....	.....	.....	54.95	2,405	60.52	2,746	27.11	2,510	3,621	31
32	88	112	58	67.90	2,847	63.33	2.637	33.85	3,081	4,290	32
33	88	112	58	69.92	2,942	67.55	2.955	28.91	2,610	3,843	33
34	.....	.....	.....	53.96	2,330	56.95	2,174	23.95	2,238	3,449	34
35	88	112	58	60.00	2,640	60.57	2 478	35.65	3,463	4,776	35
36	88	112	58	61.74	2.635	58.98	2,396	24.81	2,363	4,670	36
37	.....	.....	.....	58.51	2,612	59.19	2.632	27.57	2,503	3,852	37
38	88	251	58	66.02	2,852	63.93	2,734	26.41	2 492	3,727	38
39	88	112	80	71.22	2,850	66.56	3,123	28.72	2,554	3,808	39
40	.....	.....	.....	56.71	2,435	66.09	2,765	26.62	2,727	3,499	40
Aver'ge unfertilized yield				55.53	2,469	62.50	2,568	26.01	2,510	3,736	
Average fertilized yield.				66.63	2,847	66.11	2,879	36.27	3,291	4,356	

TABLE XLV.—Crops grown in 4-year rotation with fertilizers and manure. Increase per acre and its value. Cost of treatment and net gain or loss (—) all per acre for the 4 years of the rotation

Plot No.	Average increase per acre							Total cost of treatment	Total value of increase	Net gain or loss (—)	Pl't No.
	Corn		Oats		Wheat		Clover				
	Grain	Stover	Grain	Straw	Grain	Straw	Hay				
	Bu.	*Lb.*	*Bu.*	*Lb.*	*Bu.*	*Lb.*	*Lb.*	$	$	$	
2	10.17	362	2.41	260	7.07	213	866	8.00	15.03	7.03	2
3	8.56	342	7.40	618	7.57	345	1,021	8.00	17.26	9.26	3
5	9.00	243	3.49	249	9.29	1,031	875	8.25	17.22	8.97	5
6	10.89	232	3.23	326	11.62	615	621	8.25	18.39	10.14	6
8	13.54	386	3.76	257	13.98	1,016	637	8.25	22.14	13.89	8
9	15.57	532	5.90	419	5.61	323	267	8.25	15.09	6.84	9
11	13.11	438	3.26	329	16.92	1,318	1,162	8.25	26.70	17.45	11
12	9.67	251	—1.06	—279	.....	.....	999	8.25	.....	.....	12
14	13.46	443	5.03	495	13.93	1,291	862	10.25	23.93	13.68	14
15	14.39	327	3.87	507	15.96	1,330	833	13.50	25.34	12.84	15
17	12.94	294	4.63	480	15.15	1,353	635	12.50	23.50	11.00	17
18	13.57	431	3.81	307	15 17	1,555	686	14.50	23.96	9.46	18
20	10.56	458	3.81	198	12.96	1,237	577	12.50	20.16	7.66	20
21	11.51	452	6.82	452	14.98	1,521	893	14.50	24.86	10.36	21
23	8.88	366	3.43	297	12.24	1,155	736	12.50	19.32	6.82	23
24	12.98	611	3.60	225	12.31	922	740	12.50	21.44	8.94	24
26	4.86	192	2.58	208	3.53	222	223	9.70	7.15	—1.55	26
27	9.72	418	7.14	497	6.70	388	782	13.54	16.03	2.49	27
29	4.78	254	—.32	150	1.46	109	308	.....	4.82	.....	29
30	10.77	363	3.81	88	4.34	167	501	.....	11.73	.....	30
32	13.28	467	4.00	81	7.79	661	727	.....	17.09	.....	32
33	15.63	587	9.41	590	6.89	403	871	.....	19.94	.....	33
35	8.73	378	10.05	532	10.49	1,137	1,193	.....	21.91	.....	35
36	7.83	256	3.86	153	.....	.....	952	.....	.....	.....	36
38	8.11	299	2.44	57	2.96	214	195	.....	7.84	.....	38
39	13.90	356	2.77	403	5.36	301	596	.....	14.30	.....	39

Corn, Plots 11, 12, 35 and 36 average increase for 2 years.
Oats, yield and increase for 3 years, except Plots 11, 12, 35 and 36 increase for 1918 only.
Wheat, Plots 26, 27, 29, 30, 33, 38 and 39 average increase for 2 years.
Clover, Plots 26, 27, 29, 30, 33, 38 and 39, increase for 1918 only; other plots average increase for 1915-1918.

Table XLV shows that Plot 9, which is fertilized only on the corn crop, has given a much smaller total increase than Plot 11, fertilized only on wheat, and a similar result has followed the manuring of Plots 33 and 35. Reference to Table XLIV shows that this superiority has been largely due to the greater yield of clover following the fertilzed or manured wheat. In the 14 years' work at Germantown a similar effect on clover is shown when the wheat is manured instead of the corn, but the larger response of corn in that experiment to direct manuring and the smaller response of wheat have offset this advantage. (See Tables XXXVII and XXXVIII.)

This difference in outcome is in part due to soil and climatic conditions, which favor corn more than wheat in the Miami Valley, and wheat more than corn in northeastern Ohio.

SUMMARY AND CONCLUSIONS

The soils employed in these experiments have included silty clay loams derived chiefly from sandstones and shales and relatively deficient in lime, and heavier clay loams derived from limestones and limestone gravels. Most of these soils were below rather than above the average soils of the region in which they are located in productiveness at the time the experiments were begun, either because of geological origin or because of having been subjected to a long period of exhaustive husbandry.

Very great differences have been found in the requirement of these soils for lime, differences that may readily be predicated upon their geological origin and qualitatively demonstrated by simple chemical tests. When lime becomes deficient clover begins to fail and thus the nitrogen supply is curtailed and a general reduction in crop yields follows.

From their first occupation by the white man Ohio's soils have been relatively depleted of phosphorus, whether they have been in cultivation or in pasture, and every soil included in these experiments, whether derived from sandstones or from limestones, has responded profitably to applications of phosphorus.

Of the carriers of phosphorus used acid phosphate has proved the most effective in proportion to cost. Basic slag and steamed bonemeal are next to acid phosphate in relative effectiveness. Finely ground raw phosphate rock has returned a profit on its cost, but the effectiveness of acid phosphate is so much greater as to make the use of the raw phosphate relatively unprofitable.

Potassium has generally increased the yield, and when used as a reinforcement of phosphorus and in relatively small quantity its use at normal prices has usually been profitable, especially on potatoes and tobacco.

The maintenance of the nitrogen supply is of not less importance than that of lime or phosphorus, but the cost of purchased nitrogen is so great that the growing of leguminous crops in rotation and the careful saving and use of animal manures must be the chief means of obtaining nitrogen on the economically managed Ohio farm.

The experiments demonstrate the possibility of greatly increasing the effectiveness of manure by protecting it from the losses due to heating and leaching, and by reinforcing it with phosphorus, to replace the phosphorus that has been removed from the land in the bones or milk of the animals producing the manure.

The experiments indicate, however, that the value of manure is measured by the nitrogen and mineral elements contained; that the chief if not the sole function of its "organic matter" is to serve as a storehouse for these elements, and that if it is so managed as to release these elements before it goes to the field, through the liberation of nitrogen due to heating, or the washing out of nitrates and potash salts by leaching, its value is very materially reduced.

THE STRONGSVILLE EXPERIMENTS: ADDITIONAL DATA

The printing of this bulletin was interrupted after the preceding pages had been electrotyped, by failure to receive the necessary paper, and the delay has been utilized by preparing Table XLVIII, in which the results of the 5-year rotation at Strongsville are averaged for comparison with the duplicate rotation at Wooster (see page 596), and by adding a brief summary giving the present status of the experiment in cross-dressing the land with powdered limestone and raw phosphate rock (floats), the full plan of which and the results attained up to 1912 are given in Bulletins 260 and 305 of this Station.

Briefly stated, the plots, the treatment of which is shown in Table XLVIII, have been cross-dressed with raw phosphate rock on the north half and with powdered limestone on the south half, the treatment beginning in 1905. The phosphate rock has been used at the rate of one ton per acre and the powdered limestone at double that rate, both being applied to the surface and harrowed in after the land has been plowed for corn.

The limestone and phosphate rock have been applied to all the land, fertilized and unfertilized alike, as any other method would have interfered with the comparison of fertilizers.

During the last rotation the raw phosphate has been omitted, in order to study the residual effect of former applications, but the limestone dressings have been continued.

Owing to a mistake in application on Section E in 1915, that section is omitted from Table XLVI, which gives the total yields per acre actually harvested in this experiment up to October, 1919, on the land receiving either limestone or floats, but otherwise untreated.

TABLE XLVI.—Total yield on land cross-dressed with limestone and floats, Strongsville

		Cross-dressing	
		Limestone	Floats
Corn	bushels..	266.24	325.64
Oats	bushels..	429.35	556.06
Wheat	bushels..	125.62	178.23
Clover hay	pounds..	20,404	35,110
Timothy hay	pounds..	10,741	15,475
Soybean hay	pounds..	10,054	12,006

If, in order to arrive at a common denominator for the measurement of these different crops, we compute corn at half a dollar per bushel, oats at 40 cents, wheat at one dollar and hay at ten dollars a ton,—prices that would have been near the average on Ohio farms for a considerable period previous to the European war—the value of the total produce on the limestone-treated land would be $636, and that on the floats-treated land, $876. During this pre-war period the cost of ground limestone, spread on the land in this experiment, was approximately $3 a ton, and 22 tons per acre have been used on the 11 crops of corn included in the table. The cost of raw phosphate rock, in bulk carloads, is computed at $10 a ton and 6 tons per acre had been used before the use of this material was discontinued.

Deducting these costs from the totals given leaves $570 as the net value of the produce of the limestone-treated land and $816 as the value of that of the floats-treated land—a net gain for floats over limestone of $246.

On a part of the land under experiment acid phosphate was used at the rate of 80 pounds per acre each on corn and oats and 160 pounds on wheat, or a total of 320 pounds for each rotation. This dressing has produced the additional yields of crops shown in the next table:

TABLE XLVII.—Increase or decrease (—) produced by acid phosphate on land cross-dressed with limestone and floats, Strongsville

Crop	Cross dressing	
	Limestone	Floats
Corn.....bushels..	107.21	12.44
Oats.....bushels..	162.12	68.99
Wheat.....bushels..	110.79	32.28
Clover hay.....pounds..	17,207	1,435
Timothy hay.....pounds..	1,753	—206
Soybean hay.....pounds..	1,560	—1,254

Using the valuations above employed, the acid phosphate has increased the yield of the limestone-dressed land by a total of $332, while it has produced a further increase on the floats-dressed land of $66, thus showing that the 6 tons of floats, carrying more than 6 times as much phosphorus as that carried in the 3,600 pounds of acid phosphate used during this test, has nevertheless failed to furnish all the phosphorus the crops were capable of utilizing.

The 14-percent acid phosphate employed in this test could have been purchased in bulk carloads— that is, on the same basis as the floats—at a price that would have represented a cost of $14 a ton spread on the field. The total cost of the acid phosphate has therefore been $25, which, deducted from the value of the increase, leaves a net gain for the acid phosphate over the yield produced by the limestone of $307.

This experiment leaves no room to doubt that if we had nothing better the raw phosphate rock might be used with great profit, but the conclusion seems unavoidable that the acidulation of the phosphate renders it so much more effective as to make it the more economical material to use.

Attention should also be directed to the fact that this test has been conducted on land that requires liming. On land where liming is unnecessary the balance in favor of acid phosphate should be still greater.

TABLE XLVIII.—THE 5-YEAR ROTATION AT STRONGSVILLE. Total fertilizing materials and their cost, and total and net value of increase produced for 5-year periods and for 24 years, all calculated for one rotation of 5 years

Plot No.	Fertilizing materials for each rotation Pounds per acre					Average value of total increase per acre for each rotation					Net gain or loss (—) per acre from fertilizers for each rotation					Plot No.
	Acid phosphate	Muriate of potash	Nitrate of soda	Dried blood	Cost	First 5 yrs.	Second 5 yrs.	Third 5 yrs.	Fourth 5 yrs.	Whole period	First 5 yrs.	Second 5 yrs.	Third 5 yrs.	Fourth 5 yrs.	Whole period	
2	320	.....	.....	.....	$ 2.60	$14.10	$21.66	$16.04	$15.40	$16.43	$11.50	$19.06	$13.44	$12.80	$13.83	2
3	.....	260	.....	.....	6.50	.70	.92	—1.25	—.80	—.27	— 5.80	— 5.58	— 7.75	— 7.38	— 6.77	3
5	.....	.....	440	50	14.40	.77	.77	2.48	5.49	3.29	—13.63	—13.63	—11.92	— 8.91	—11.11	5
6	320	.....	440	50	17.00	18.13	24.68	22.22	23.35	22.01	1.13	7.68	5.22	6.35	5.01	6
8	320	260	.....	.....	9.10	16.47	19.77	22.10	18.75	18.24	7.37	10.67	13.00	9.65	9.14	8
9	.....	260	440	50	20.90	3.36	2.90	6.58	10.43	6.73	—17.54	—18.00	—14.32	—10.47	—14.23	9
11	320	260	440	50	23.50	21.79	24.69	23.71	26.28	24.35	— 1.71	1.19	.21	2.78	.85	11
12	320	260	680	50	30.70	22.33	26.57	24.22	31.28	26.18	— 8.37	— 4.13	— 6.48	.58	— 4.52	12
14	240	180	280	50	16.05	18.71	19.43	18.39	20.03	19.39	2.66	3.38	2.34	3.98	3.34	14
15	160	100	120	50	8.60	9.91	13.46	14.24	13.32	11.88	1.31	4.86	5.64	4.72	3.28	15
17	480	260	220	25	17.60	13.91	28.58	25.26	30.33	24.31	— 3.69	10.98	7.66	12.73	6.71	17
18	Yard manure, 16 tons.....				?	16.65	20.16	25.16	26.05	22.28	?	?	?	?	?	18
20	Yard manure, 8 tons.....				?	12.56	12.62	21.22	17.25	14.22	?	?	?	?	?	20
21	Same as 17, but nitrogen in oilmeal.....				17.60	18.51	25.05	20.77	19.66	21.18	.91	7.45	3.17	2.06	3.58	21
23	Same as 17, all nitrogen in dried blood.....				17.60	20.54	24.14	20.63	23.89	22.06	2.94	6.54	3.03	6.29	4.46	23
24	Same as 17, nitrogen in sulphate ammonia...				17.60	20.46	24.93	21.71	21.89	21.93	2.86	7.33	4.11	4.29	4.33	24
26	Same as 11, phosphorus in bonemeal.....				23.50	20.47	26.02	21.59	21.87	22.86	— 3.03	2.52	— 1.91	— 1.63	— .64	26
27	Same as 11, nitrogen in nitrate of lime*.....				23.50	17.34	24.03	21.22	19.40	19.90	— 6.16	.53	— 2.28	1.80	— 1.16	27
29	Same as 11, phosphorus in basic slag.....				23.50	23.19	25.52	21.22	25.47	23.97	— .31	2.02	— 2.28	1.87	.37	29
30	Same as 17, nitrogen in tankage†.....				17.60	24.91	35.55	25.39	26.18	26.92	7.31	17.95	7.79	8.58	9.32	30
32	320	260	220	25	16.30	20.98	24.38	20.59	24.47	22.33	4.68	8.08	4.29	8.17	6.03	32
33	320	260	110	15	12.70	20.91	24.53	18.71	24.61	21.57	8.21	11.83	6.01	11.91	8.87	33
35	320	130	440	50	20.25	20.36	23.98	23.96	29.05	24.62	.11	3.73	3.71	8.80	4.37	35
36	320	65	440	50	18.62	22.14	26.81	21.37	27.50	24.46	3.52	8.19	2.75	8.88	5.84	36
38	100	10	Tankage (7-30) 100		?	12.23	20.38	13.68	11.09	13.78	?	?	?	?	?	38
39	Yard manure, 16 tons				?	8.33	14.73	22.70	24.75	18.63	?	?	?	?	?	39

*Since 1910. Previously, same quantities of elements as on Plot 11, with nitrogen in nitrate of soda and phosphorus in dissolved boneblack.

†Since first period. Smaller applications during first period.

The table shows that in this experiment the maximum effectiveness of most of the fertilizers was reached during the second period, although in a number of cases, including the manures, the fourth period shows the largest increase. On this land—starting as an old pasture—phosphorus has had an even greater effect than at Wooster, while the return from nitrogen and potassium has been relatively small. The effect of nitrogen, however, has increased during the later periods.